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ABSTRACT

This guide provides information on how to create schools that provide better learning environments for students and teachers, cost less to operate, and help protect the environment. The guide is organized into three core sections. The first provides an overview and two interrelated discussions on what is a high performance school building and why are such schools valuable. The second section provides issue-specific questions that decision-makers can ask their design team as a means of driving the project toward the highest achievable levels of performance. The final section contains 16, 2-page "briefs" that describe each of the key components which, when integrated as elements of "whole building" design, result in a high performance building. Each brief describes what the building block is, why it's important to students and teachers, as well as to the school's bottom line; how it can be incorporated into the school's design; how it influences other building components and systems; and where more detailed information can be found. (GR)

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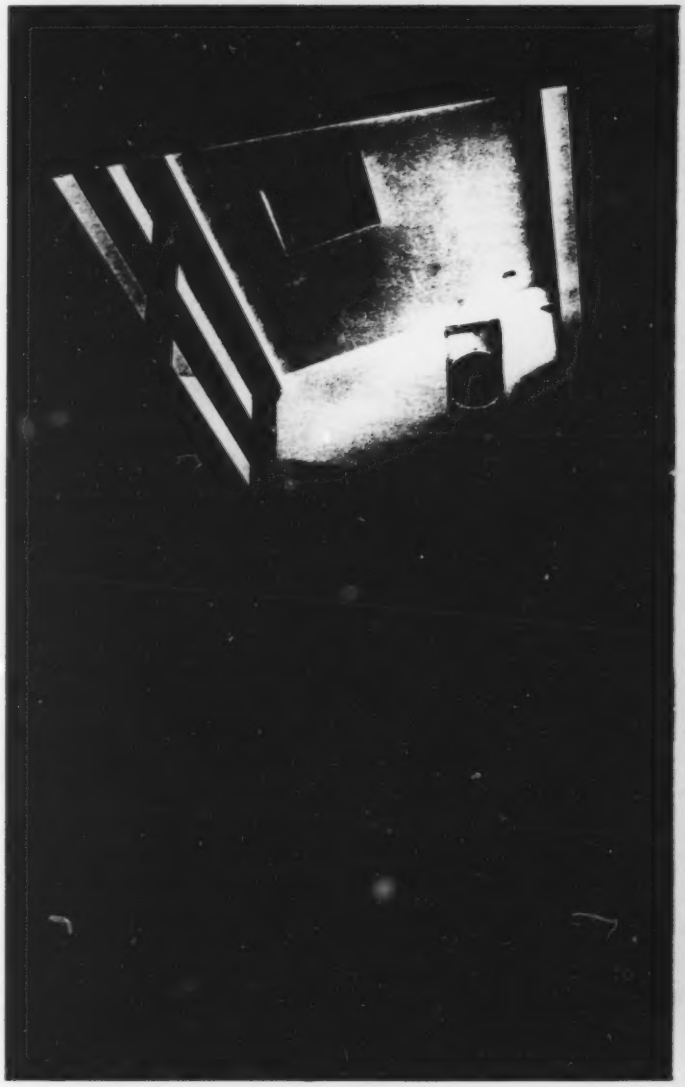
Resource & Strategy Guide

High Performance School Buildings



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High Performance School Buildings

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Disclaimer

This document has been developed by the Sustainable Buildings Industry Council (SBIC). It is designed to serve as course material for SBIC's *High Performance School Buildings* education campaign. The content presented in the *Resource & Strategy Guide* has been reviewed by a technical review committee with broad-based expertise in energy and education. Although great care has been taken in preparation of this document, no warranties, either expressed or implied, are made in connection with the accuracy or completeness of the information contained herein, and no responsibility can be assumed by SBIC, the U.S. Department of Energy, the U.S. Department of Education, the U.S. Environmental Protection Agency, Southern California Edison Company, Pacific Gas & Electric Company, California Energy Commission, the Collaborative for High Performance Schools, the National Concrete Masonry Association, or any of their respective consultants for any claims arising herewith. Comments, criticisms, clarifications, and suggestions regarding format and content are welcome.

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SBIC is a nonprofit organization whose mission is to advance the design, affordability, energy performance, and environmental soundness of residential, institutional, and commercial buildings nationwide. As the foremost national resource for sustainable design and product information, SBIC offers professional training, consumer education, and energy analysis tools. SBIC publishes accurate, easy-to-use guidelines, software, and general information about energy conservation measures, energy efficient equipment and appliances, daylighting, and sustainable architecture. Those interested in having SBIC conduct similar workshops in their area are encouraged to contact Ellen Larson at 202-628-7400 x 211 or by e-mail at ELarson@SBICouncil.org. The Council also produces workshops and seminars geared toward improving resource conservation, indoor environmental quality, and energy performance in other building types throughout the nation. For more information, contact:

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High Performance School Buildings Resource & Strategy Guide

The *High Performance School Buildings Resource & Strategy Guide* is a simple, easy-to-use roadmap for use in creating schools that:

- Provide better learning environments for students and teachers;
- Cost less to operate; and
- Help protect the environment.

Background

According to a recent General Accounting Office report, an estimated 6,000 new schools will be built nationwide by the year 2007. The sheer scope of this undertaking makes it clear that the U.S. is faced with a once-in-a-lifetime opportunity to shape the built environment in ways that will influence the lives of K-12 students for generations to come. High performance school buildings – those which incorporate the very best in today's design strategies and building technologies – can help make the most of this remarkable opportunity.

"High performance facilities are a critical part of the equation for improving student outcomes in this country."

– Jack Lyons
Education Facilities Program Manager, U.S. Department of Education

Designing and procuring energy- and resource-efficient schools is possible right now. All that's needed is the vision, determination, and knowledge to make high performance the *standard of performance* in school facility design and construction. This *Resource & Strategy Guide* provides the requisite knowledge, and is intended for those with the vision and determination to put this knowledge to work in building new schools.

Audience

The *Resource & Strategy Guide* has been developed specifically for those who control the process by which new schools are designed and built: school superintendents, business officials, board members, and other key decision-makers. It is not intended as the sole reference for architects and other design professionals, who have their own, more technical guidance for creating high performance buildings. It is structured to meet the needs of those who hire and manage the services of these professionals, and as a guide for further research by A/Es and others engaged in school facility design.

Organization

The *Guide* is organized into three core sections.

Section 1 provides an overview and two interrelated discussions:

- What is a High Performance School Building?
- Why is a High Performance School Building Valuable?

Schools currently spend more than $6 billion per year on energy, exceeding the combined cost of supplies and books. The U.S. Department of Energy estimates that energy costs, when combined with the costs of water, wastewater processing, and trash collection, average out at $125 per student per year. High performance buildings can reduce this number by up to $50 per student per year!

Section 2 is the *Process Guide*, which provides issue-specific questions that decision-makers can ask their design team as a means of driving the project toward the highest achievable levels of performance. The questions are organized according to the key phases of the development process:

- Programming and Goal Setting;
- Site Analysis;
- Selecting the A/E Team;
- Schematic Design;
- Design Development;
- Construction Documents;
- Bidding and Negotiation; and
- Construction Administration.

Section 3 contains the *Building Blocks* of High Performance School Buildings – 16 two-page 'briefs' that describe each of the key components which, when integrated as elements of 'whole building' design, result in a high performance building. Each brief describes:

- What the *Building Block* is;
- Why it's important to students and teachers, as well as to the school's bottom line;
- How it can be incorporated into the school's design;
- How it influences other building components and systems; and
- Where more detailed information can be found.

Taken together, the three sections provide a new and unique method for guiding the design and development process so that any new school – no matter what the budget – can achieve the highest performance levels possible for its particular circumstances.

What is a High Performance School Building?

Characteristics

A high performance school building has three key characteristics:

- It is **healthy and productive** for students and teachers, in that it provides...
  - High levels of acoustic, thermal, and visual comfort;
  - Large amounts of natural daylight;
  - Superior indoor air quality; and
  - A safe and secure environment.
- It is **cost effective** to operate and maintain, because it s design employs...
  - Energy analysis tools that optimize energy performance;
  - A life cycle cost approach that reduces the total costs of ownership; and
  - A commissioning process that ensures the facility will operate in a manner consistent with design intent.
- It is **sustainable**, because it integrates...
  - Energy conservation and renewable energy strategies;
  - High performance mechanical and lighting systems;
  - Environmentally responsive site planning;
  - Environmentally preferable materials and products; and
  - Water-efficient design.

Creating a school with these characteristics is not difficult, but it does require an integrated, whole building approach to the design process. Key systems and technologies – the 'building blocks' of a high performance school – must be considered holistically, from the very beginning of the design process, and optimized throughout based on their *combined* impact on the comfort and productivity of students and teachers. At the conclusion of the process, the entire facility will be optimized to achieve long-term value and performance. The result will be a finished school that is an enduring asset to its community; one that enhances teaching and learning, reduces operating costs, and protects the environment.

Building Blocks

The following list summarizes the main Building Blocks of a high performance school – the components which, when integrated as elements of a 'whole building' design, will do the most to create a school that is healthy and productive, cost effective and sustainable. Each of these topics is covered in detail under the *Building Blocks* section of the *Resource & Strategy Guide*.

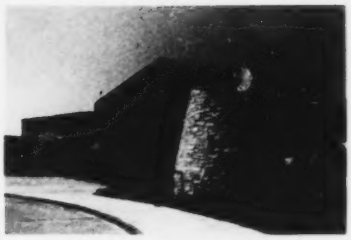
- **Acoustic Comfort** – Students and teachers can hear one another without shouting. Noise from inside and outside the classroom is minimized.
- **Commissioning** – The school operates in accordance with design intent and meets the needs of the owner. This is made possible by implementing a formal commissioning process – a kind of 'systems check' for the facility. The process tests, verifies,

Boscawen Elementary School
Boscawen, NH

This 420-student school is daylit and also utilizes 100% fresh outdoor air in a system that ensures superior air quality even as it saves energy.

"It's light, it's bright, and the use of space is so efficient for us, especially having come from a mid-1860s building. I've already sensed a calmness in the new building that is wonderful. It's an environment that's going to enhance our educational efforts. We expect to take off and do some remarkable things. The environment we're now living and working in will help us do that."

– Jane Lacasse, Principal



Roy Lee Walker Elementary School
McKinney, Texas
Independent School District

In one year, sufficient rainwater flows off the roof of this new K-5 school north of Dallas to meet the school's needs six times over. A portion of this water is captured and stored in cisterns – enough to water the grounds and flush the toilets year round.

Dena Boer Elementary School
Salida, CA

Skylights do double duty in this 800-student, K-5 school. They provide high quality light to the classrooms, while at the same time helping to vent air to the outside. In conjunction with operable windows, this allows for natural ventilation when the weather outside is temperate, thus saving on heating and cooling energy costs.

"The skylights create an open, bright work environment. We just seem to have more room. Visitors say it sure is a pleasant place to come into."

– Rick Bartkowski, Principal

and fine-tunes the performance of key building systems so that they perform at the highest levels of efficiency.

- **Daylighting** – As much natural daylight as cost-effectively possible is provided, particularly in classrooms where it can do the most good. Daylighting systems are designed to avoid excessive heat loss or gain and to minimize glare.
- **Energy Analysis Tools** – The facility is designed to reduce short- and long-term energy costs as much as possible while maintaining a high quality learning environment. Energy analysis tools are used to predict the energy impacts of alternative design strategies and to select the best combinations of quality and energy efficiency.
- **Energy Efficient Building Shell** – The walls, floors, roofs, and windows of the school are as energy efficient as economically practicable. The building shell integrates and optimizes insulation levels, glazing, shading, thermal mass, air leakage, and light-colored exterior surfaces.
- **Environmentally Preferable Materials and Products** – To the maximum extent possible, the school incorporates materials and products that are durable, non-toxic, derived from sustainable-yield processes, high in recycled content, and easily recycled themselves.
- **Environmentally Responsive Site Planning** – To the extent possible, the school's site conserves existing natural areas and restores damaged ones, minimizes stormwater runoff and controls erosion, and enhances the building's high performance features.
- **High Performance HVAC** – The school's heating/ventilating/ air conditioning (HVAC) system uses high efficiency equipment, is 'right sized' for the estimated demands of the facility, and includes controls that boost system performance.
- **High Performance Electric Lighting** – Students and teachers work in a high quality visual environment that stimulates learning while saving energy. The school's lighting system uses high efficiency lamps and ballasts, optimizes the number of light fixtures in each room, incorporates controls that ensure peak system performance, and successfully integrates electric lighting and daylighting strategies.
- **Life Cycle Cost Analysis** – The school is optimized with a view toward its total cost of ownership over time. Initial, operating, and maintenance/repair/replacement costs are compared for numerous design alternatives using a life cycle cost analysis tool or tools. The best combination of quality and long-term cost effectiveness is selected.
- **Renewable Energy** – The school maximizes the cost-effective use of renewable systems to meet its energy needs. During the design process, the following systems are systematically evaluated and considered: passive solar heating, solar hot water, active solar (for space heating), geothermal heat

pumps, natural ventilation, wind-generated electricity, photovoltaically generated electricity, and green power.

- **Safety and Security** – Students and teachers feel safe anywhere in the building or on the grounds. A secure environment is created primarily by *design*: opportunities for natural surveillance are optimized, a sense of territoriality is reinforced, and access is controlled. Security technology is used to enhance, rather than substitute for, the design features.
- **Superior Indoor Air Quality** – Students and teachers suffer no ill effects from the air inside the school. Sources of contamination are controlled, adequate ventilation is provided, and moisture accumulation is prevented.
- **Thermal Comfort** – Occupants are comfortable at all times. Temperature and humidity remain in the 'comfort zone.' Hot, stuffy rooms and cold, drafty ones are eliminated. Teachers have control over thermal conditions in individual classrooms.
- **Visual Comfort** – A rich visual environment is provided. The lighting for each room is 'designed', not simply specified. Daylight and electric light are integrated and optimized. Glare is eliminated.
- **Water Efficiency** – The school uses as little off-site water as possible to meet its needs. The school controls and reduces water run-off from its site, consumes fresh water as efficiently as possible, and recovers and reuses graywater to the extent feasible.

Why Is A High Performance School Building Valuable?

Benefits

A high performance building – one that is healthy and productive, cost effective, and sustainable – supports a school's mission by delivering at least seven key benefits:

- Better student performance;
- Increased average daily attendance;
- Increased teacher satisfaction and retention;
- Reduced operating costs;
- Reduced liability exposure;
- A positive influence on the environment; and
- Increased opportunities for using the facility itself as a teaching tool.

These benefits only accrue if high performance is established as a specific design goal from the very beginning, and if it is fought for, with perseverance and determination, throughout the course of the development process. A focus on student and teacher outcomes, coupled with concern for the environment and a commitment to cost-effectiveness, will help ensure that the effort is successful and that any school – no matter what its budget – achieves the highest performance level possible in light of its particular circumstances.

Better Student Performance

A growing number of studies are confirming the relationship between a school's physical condition – especially its lighting and indoor air quality – and student performance. One recent study of school districts in California, Washington, and Colorado strongly indicates a correlation between increased daylighting and improved student performance. In the California district, for example, students with the most daylighting progressed 20% faster on math tests and 26% faster on reading tests in one year in comparison to those with the least amount of daylight. These results echo findings in a similar study conducted on schools in North Carolina. The message is clear, and it confirms what teachers, students, and parents have known anecdotally for years: a better facility – one with great acoustics, lighting, indoor air quality, and other high performance features – will deliver improved student outcomes.

Increased Average Daily Attendance

A high performance school provides superior indoor air quality by controlling sources of contaminants, providing adequate ventilation, and preventing moisture accumulation. As a consequence, pollutants are kept out of the classroom, stale air is eliminated, and mold growth is inhibited – all tactics designed to reduce the sources of health problems and reduce the spread of airborne infections. The result will be fewer sick days for students and teachers, especially those suffering from asthma or other respiratory ailments.

Durant Road Middle School
Wake County, NC

"The daylit classrooms have increased the well being of the students and teachers, and are at least partially responsible for our record high attendance rates. We are running about 3% ahead of the rest of the county in attendance. We stay around 98%.

– Tom Benton, Principal
Durant Road Middle School

The results of the analyses of the three districts are remarkably consistent: all show positive daylight effects with highly significant results. The actual magnitude of the effects is less important than the observation that a consistent effect can be found in three very different school districts.

- *We found a uniformly positive and statistically significant correlation between the presence of daylighting and better student test scores in all three districts.*
- *We found that the positive effect of daylighting was distinct from all the other attributes of windows."*

Excerpted from Daylighting in Schools: An Investigation into the Relationship Between Daylighting and Human Performance

– Prepared by the Heschong Mahone Group for the Pacific Gas and Electric Company on behalf of the California Board for Energy Efficiency Third Party Program.

"I have noticed a big difference in my health since we've been in the new school. I had a lot of absenteeism – in fact, I was hospitalized in the old building. In the new school, I won't say that I'm cured of asthma – I still have it and I still have allergies – but I really don't have many problems at all and I'm feeling great."

– Teacher at a new school in New Hampshire using the Advantage Classroom™ design concept.

Oquirrh Hills Elementary School
Kearns, Utah

A light-colored, well-insulated roof, a high efficiency lighting system, energy management controls, and low-e windows all combined to reduce the operating costs of this elementary school near Salt Lake City by $22,000 annually.

Brunswick High School
Brunswick, ME

This 1200-student high school has been designed – inside and out – to take educational advantage of its environmentally friendly systems and technologies. A high performance energy management system has been installed and is connected to a touch pad monitor that any student of teacher can use to check the real-time use of oil and electricity throughout the building. In some rooms, transparent ceiling tiles have been installed so students can see heating and cooling, electricity and ventilation air move around the school. And outside, a natural wetlands, 'mini-arboretum' and stormwater treatment facility all serve as outdoor labs for classes throughout the year.

Increased Teacher Satisfaction and Retention
High performance classrooms are designed to be pleasant and effective places to work. They are visually and thermally comfortable, incorporate good acoustics to help minimize distraction, and provide indoor air that is fresh and clean. Such environments yield tangible results in terms of recruiting and retaining teachers, and in improving their overall satisfaction with their positions.

Reduced Operating Costs
Through the use of life cycle costing methods, high performance schools are specifically designed to minimize the long-term costs of ownership. They use less energy and water than standard schools and are easy to maintain. As a consequence, overall operating costs are low and will remain so over the life of the facility.

Reduced Liability Exposure
Because high performance schools are healthy – in particular, because they emphasize superior indoor air quality – high performance school buildings reduce a district's exposure to health-related lawsuits. They also provide good classroom acoustics, minimizing potential conflicts with the Americans with Disabilities Act.

Positive Impact on the Environment
High performance school buildings are consciously designed to respond to and positively influence the environment. They are energy and water efficient. They use durable, non-toxic materials that are high in recycled content and are themselves easily recycled. They preserve pristine natural areas on their sites and restore damaged ones. And they use non-polluting, renewable energy to the greatest extent possible. As a consequence, high performance school buildings are good environmental citizens, and they are designed to stay that way throughout their entire life cycles.

Using the Facility as a Teaching Tool
Many of the technologies and techniques used to create high performance schools can also be used as teaching tools. Renewable energy systems – solar, solar electric, and wind – are ideal for 'hands-on' demonstrations of scientific principles. Wetlands, nature preserves, and other site amenities can be used as outdoor laboratories. Mechanical and lighting equipment and controls can be used to illustrate lessons on energy use and conservation. And daylighting systems can help students understand the daily and yearly movements of the sun. Although any school building can be used as a teaching tool, many of the technologies and strategies commonly found in high performance facilities are particularly suitable for educational purposes.

Introducing the Process Guide

The *Process Guide* presents a step-by-step method for managing the design process in ways that ensure the desired outcome: a high performance school building.

The *Guide* contains a series of questions, organized by design phase, that the 'owners' of a new school (the superintendents, business officials, board members, and others who are guiding the facility development process) can use to ensure that their design team actively considers *all* the key components of a high performance school during each phase of the development process.

Using the *Process Guide*

Over the course of designing and building a new facility, school representatives will meet regularly with their design team to discuss progress. The *Process Guide* should be used to help guide discussion during these meetings.

The *Guide* is divided into eight sections corresponding to key phases in the design/development process:

- Site Analysis
- Selecting the A/E Team
- Programming and Goal Setting
- Schematic Design
- Design Development
- Construction Documents
- Bidding and Negotiation
- Construction Administration

The appropriate section of the *Process Guide* should be consulted at the start of each phase. The list of questions should be used, throughout this phase of the process, to help frame productive discussions with the design team.

The questions in each section of the *Process Guide* are designed to address the key *Building Blocks* of any high performance school:

> Acoustic Comfort, Commissioning, Daylighting, Energy Analysis Tools, Environmentally Preferable Materials and Products, Environmentally Responsive Site Planning, High Performance Heating/Ventilating/Air Conditioning Systems, High Performance Electric Lighting, Life Cycle Cost Analysis, Renewable Energy, Safety and Security, Superior Indoor Air Quality, Thermal Comfort, Visual Comfort, and Water Efficiency.

For a quick overview of each of these *Building Blocks* – and a guide to more detailed resources on each topic – consult Section 3 of the *High Performance School Buildings Resource and Strategy Guide*.

"In times of limited resources and faced with an increasing demand for student achievement and accountability, it's critically important for local districts to embrace the strategies and concepts that lead to high performance school buildings."

– Duwayne Brooks
Assistant Superintendent of Public Instruction
California Department of Education

A study by the General Accounting Office shows the types of impacts substandard buildings can have on environmental conditions, and consequently, on teaching and learning. The table below indicates the percentage of schools nationwide reporting unsatisfactory conditions in six key environmental areas (from GAO Report GAO/HEHS –95-61).

Acoustics	*28.1%*
Ventilation	*27.1%*
Security	*24.2%*
Heating	*19.2%*
Air Quality	*19.2%*
Lighting	*15.6%*

Questions to ask as a potential or actual site is being reviewed.

1. **Acoustic Comfort**
   - ❒ Are there major sources of noise near the site (e.g., highways, shopping areas)?
   - ❒ Can the site be used to minimize the impacts of these noise sources (e.g., through planting, earth berms, etc)?

2. **Commissioning**
   - ❒ N/A

3. **Daylighting**
   - ❒ Does the site allow the building to be oriented on an east-west axis, maximizing southern exposure?
   - ❒ How will site elements (e.g., existing trees or adjacent buildings) influence the building's access to sunlight?
   - ❒ Can the site accommodate one-story construction to allow skylights or roof monitors in the classrooms?

4. **Energy Analysis Tools**
   - ❒ N/A

5. **Energy Efficient Building Shell**
   - ❒ N/A

6. **Environmentally Preferable Materials & Products**
   - ❒ N/A

7. **Environmentally Responsive Site Planning**
   - ❒ Can existing natural areas on the site be preserved?
   - ❒ Does the site lend itself to controlling stormwater runoff?
   - ❒ What areas of the site could be used as 'outdoor laboratories' for teaching?
   - ❒ Is there good pedestrian, mass transit, and/or bicycle access?

8. **High Performance HVAC**
   - ❒ N/A

9. **High Performance Electric Lighting**
   - ❒ N/A

10. **Life Cycle Cost Analysis**
    - ❒ N/A

11. **Renewable Energy**
    - ❒ Does the site have good solar access – for daylighting, active and passive solar heating, solar hot water, and/or photovoltaic systems?
    - ❒ Could the site use wind power to generate electricity?

12. **Safety and Security**
    - ❒ Are there clear lines of sight to and from the school building throughout the site?
    - ❒ Are there areas (depressions in the ground, stands of trees, thick shrubs) where people can be hidden from view?

13. **Superior Indoor Air Quality**
    - ❒ Is the site near any sources of outdoor pollution?

14. **Thermal Comfort**
    - ❒ Are there prevailing breezes that could be used to help naturally ventilate the building?

15. **Visual Comfort**
    - ❒ Does the site provide special views that should be preserved?

16. Water Efficiency

- ❒ Does the site lend itself to the use of high efficiency irrigation techniques?
- ❒ Could the site accommodate on-site wastewater treatment?

Questions to ask prospective Architecture/Engineering teams to ensure that they have the necessary experience and qualifications to deliver a high performance school.

1. **Acoustic Comfort**
   - ❒ How has the team addressed acoustic performance in previous projects?
   - ❒ What specific strategies has the team used to ensure acoustic quality?
   - ❒ How has the team applied these strategies in classrooms?

2. **Commissioning**
   - ❒ Have any of the team's previous buildings (especially schools) gone through a commissioning process?
   - ❒ How detailed was the commissioning? Who acted as commissioning agent?
   - ❒ What were the results?

3. **Daylighting**
   - ❒ What examples can the team provide of previous projects that incorporate daylighting?
   - ❒ Are any of these examples schools, especially classrooms?
   - ❒ What daylighting strategies did the team use?
   - ❒ Are the occupants satisfied with the results?
   - ❒ Are the strategies saving energy? How much?
   - ❒ What analysis tool does the team use to optimize performance of the daylighting systems it designs?

4. **Energy Analysis Tools**
   - ❒ What energy analysis tool(s) does the team use on its projects?
   - ❒ How does it use the tool(s) to reduce energy consumption in its designs?
   - ❒ Has it applied the tools to school design? What were the results?
   - ❒ What tool(s) does the team propose for the project under discussion?

5. **Energy Efficient Building Shell**
   - ❒ How has the team achieved energy efficient walls, floors, and roofs on previous projects?
   - ❒ What key techniques, materials, and products were used and what was the resulting impact on energy performance?
   - ❒ Are the systems still performing as designed?

6. **Environmentally Preferable Materials and Products**
   - ❒ What experience does the team have in specifying environmentally responsible materials and products in its projects?
   - ❒ Does the team have knowledge of how these materials and products can be procured and how they are installed?
   - ❒ Does the team have knowledge of how these materials and products perform over time?
   - ❒ Has the team ever specified environmentally responsible materials and products for schools?

7. **Environmentally Responsive Site Planning**
   - ❒ Has the team created environmentally responsible site plans before?
   - ❒ What were the key features and how are they performing?

8. **High Performance HVAC (heating/ventilating/air conditioning)**
   - ❒ Does the team specify high performance HVAC systems as standard practice?
   - ❒ What tools does the team use to analyze and optimize the performance of HVAC systems?
   - ❒ What high performance HVAC systems has the team put in place in previous projects (preferably schools)?
   - ❒ How much energy was saved as a direct result of specifying these systems?
   - ❒ How have these systems performed over time?

9. **High Performance Electric Lighting**
   - ❒ Does the team have experience designing high performance electric lighting systems (preferably in schools)?
   - ❒ Are these systems providing a high quality visual environment *and* saving energy?

- ❒ What is the team's experience in integrating daylighting and electric lighting systems?
- ❒ What tool(s) does the team use to analyze and optimize the *combined* performance of daylighting and electric lighting systems?

10. Life Cycle Cost Analysis

- ❒ What life cycle cost methodology does the team use on its projects?
- ❒ How does it use the methodology to reduce the total ownership costs of the buildings it designs?
- ❒ Has it applied the methodology to school design? What were the results?
- ❒ What methodology does the team propose for the project under discussion?

11. Renewable Energy

- ❒ What is the team's experience designing and/or installing renewable energy systems?
- ❒ What specific systems have they used or installed (preferably in schools)?
- ❒ How much energy are these systems saving?
- ❒ Are they still performing as intended?

12. Safety and Security

- ❒ Does the team have experience with Crime Prevention Through Environmental Design (CPTED)?
- ❒ How has the team incorporated CPTED principles into previous projects (preferably schools)?
- ❒ How does the team balance the use of security technology and the use of CPTED principles in its buildings? Does it emphasize 'security by design' first and technology second?

13. Superior Indoor Air Quality

- ❒ What is the team's approach to delivering superior indoor air quality?
- ❒ In previous projects (preferably schools), how has the team addressed: controlling sources of contaminants in a building, providing adequate ventilation, and avoiding moisture accumulation?
- ❒ Have any of their buildings experienced indoor air quality problems requiring remedial action?

14. Thermal Comfort

- ❒ What is the team's approach to maintaining thermal comfort in the buildings they design?

15. Visual Comfort

- ❒ What is the team's approach to ensuring visual comfort in the buildings they design?
- ❒ Do they have examples (preferably classrooms) that can be visited and 'test driven'?

16. Water Efficiency

- ❒ What is the team's experience with water-efficient landscaping, water use reduction techniques, and/or innovative wastewater treatment systems?
- ❒ Have they applied any of these techniques to schools?
- ❒ What have the results been?

Questions that will help establish clear, explicit high performance goals as early as possible in the design process – during development of the building's program (the document detailing the basic scope of the project, the types and number of rooms required, etc.).

1. Acoustic Comfort

- ❒ Have good classroom acoustics been established as a design goal for the project?

2. Commissioning

- ❒ Has the team committed to, and budgeted for, commissioning as a basic component of the project?
- ❒ Has a commissioning agent been engaged?

3. Daylighting

- ❒ Has optimized daylighting been specifically established as a design goal for the school and, in particular, for the classrooms?

4. Energy Analysis Tools

- ❒ Is the design team required to use an energy analysis tool to help maximize the building's energy performance?
- ❒ What tool has been selected?
- ❒ At what stages in the design process will the tool be used, and what types of analyses will be performed?
- ❒ Has an energy use goal (i.e., a maximum amount of nonrenewable energy the school should consume in a year) been established? What is it (e.g., __% better than the building code requires)?

5. Energy Efficient Building Shell

- ❒ Has providing an energy efficient building shell been established as a goal for the project?
- ❒ Does the basic programming allow windows on the east and west to be smaller (to reduce unwanted heat gain) and those on the north and south to be larger (to enhance daylighting opportunities)? For example, does the programming group functions that may need less glazing (auditoriums, kitchens, etc.) on the east and west, and those that will benefit most from daylight (classrooms, corridors, etc.) on the north and south?

6. Environmentally Preferable Materials and Products

- ❒ Has using environmentally preferable materials and products (to the extent feasible) been established as a design goal?
- ❒ Has the meaning of 'environmentally preferable' been agreed to by the owner and the design team?

7. Environmentally Responsive Site Planning

- ❒ Has preserving natural areas on the site been established as a design goal?
- ❒ Is minimizing stormwater runoff a design goal for the site?

8. High Performance HVAC

- ❒ Is using high efficiency heating, ventilating, and air conditioning equipment a design goal for the project?
- ❒ Is 'right sizing' this equipment (by accurately predicting demand and sizing the equipment to meet it) a design goal?

9. High Performance Electric Lighting

- ❒ Is a high performance electric lighting system (especially in classrooms) a design goal?
- ❒ Is optimizing the interaction between the electric lighting system and any daylighting strategies a design goal?

10. Life Cycle Cost Analysis

- ❒ Has using some form of life cycle cost analysis methodology been established as a requirement for the design team?
- ❒ What methodology will be used?

- ❒ What basic assumptions (e.g., projected life of the facility, projected energy costs, rate of inflation, etc.) have been built into the methodology? Have these assumptions been agreed to by all parties?

11. Renewable Energy

- ❒ Is maximizing the cost-effective use of renewable energy a design goal for the project?
- ❒ What percentage of the projected annual energy use of the facility should be provided by renewable energy systems? Has this percentage been agreed to by all parties?

12. Safety and Security

- ❒ Has security been established as a design goal for the project?
- ❒ As part of programming, are basic room placements and adjacencies being considered in terms of their impacts on safety and security (e.g., is the main entrance visible from the administrative offices, etc.)?

13. Superior Indoor Air Quality

- ❒ Has superior indoor air quality been established as a design goal for the project?

14. Thermal Comfort

- ❒ Has thermal comfort been established as a design goal, especially for the classrooms?

15. Visual Comfort

- ❒ Has visual comfort been established as a design goal, especially for the classrooms?

16. Water Efficiency

- ❒ Has water efficiency been established as a design goal for the project?
- ❒ Have water use goals for the school been established?

Questions to ask during the conceptual design phase, when key decisions on the basic scale and layout of the facility are being made, and the project's overall scope and direction are being established. Modifying these decisions at later stages may prove to be difficult and costly.

1. Acoustic Comfort

- ❒ Does the basic layout of the classrooms help or hinder good acoustics (i.e., does it damp or magnify sound reverberation)?
- ❒ Do any of the classrooms face sources of outside noise? If so, what measures are proposed to reduce the impact of this noise?
- ❒ Are any of the classrooms located next to sources of inside noise (music rooms, rooms with amplified sound systems)? If so, what measures are proposed to reduce the impact of this noise?

2. Commissioning

- ❒ Is appropriate design documentation being collected by/delivered to the commissioning agent?

3. Daylighting

- ❒ What basic strategies are being considered for bringing daylight into the school, particularly the classrooms?
- ❒ What strategies are being considered to control unwanted heat gain and glare?
- ❒ What tools are being used to analyze the impact of any daylighting strategies on the electric lighting system and on visual comfort and energy use?
- ❒ What are the preliminary results of these analyses?

4. Energy Analysis Tools

- ❒ Have the energy analysis tool(s) selected for the project been used to project energy consumption at least once (preferably several times) during this phase of design?
- ❒ Do the results meet or exceed the energy goal for the facility?

5. Energy Efficient Building Shell

- ❒ What basic assemblies and configurations are being considered for the walls, floors, and roofs of the facility?
- ❒ What types of materials (glazing, shading, insulation, air barriers, structural materials) are being considered?
- ❒ How are trade-offs (between amounts of window versus wall, between one type of glazing versus another, etc.) being analyzed, and how will the overall performance of the shell as a whole be optimized?
- ❒ How are the impacts of thermal mass being addressed?
- ❒ Are light colored surfaces (particularly roofing) being considered as a means of reducing heat gain?

6. Environmentally Preferable Materials and Products

- ❒ What types of environmentally preferable materials and products are being considered and where will they be used?
- ❒ Does the basic design facilitate recycling by students and staff?

7. Environmentally Responsive Site Planning

- ❒ Is the building, particularly the classroom wings, oriented in a predominantly east-west direction to facilitate access to daylight?
- ❒ Does the design preserve existing natural areas of the site?
- ❒ Does the design help control stormwater runoff?
- ❒ Does the design minimize areas covered with impervious surfaces (e.g., parking lots, paved walkways, etc.)?

8. High Performance HVAC

- ❒ What type of HVAC system is being considered for the school?
- ❒ Why is this system optimal from a comfort/energy performance perspective?
- ❒ How are the interactions between the HVAC system and other key building systems (lighting, daylighting, building shell) being analyzed and optimized?

- ❒ Is natural ventilation being considered? If so, are its potential impacts on HVAC performance being factored into the analytic process?

9. High Performance Electric Lighting

- ❒ What electric lighting system is being proposed for the school and, in particular, for the classrooms?
- ❒ What are its energy and visual performance benefits?
- ❒ How does it interact with the daylighting strategies being used?
- ❒ How are these interactions being analyzed and optimized?

10. Life Cycle Cost Analysis

- ❒ Has the life cycle cost methodology selected for the project been used to compare and optimize alternative design strategies at least once (preferably several times) during this phase of the process?

11. Renewable Energy

- ❒ What renewable energy strategies are being considered for the school?
- ❒ How much energy will they save?
- ❒ What are their life cycle cost benefits?
- ❒ How will they impact the site plan or the building design?
- ❒ How will they impact other building systems (lighting, electrical, HVAC, building shell)?

12. Safety and Security

- ❒ How have Crime Prevention through Environmental Design (CPTED) principles been applied during this phase of the process?
- ❒ Are opportunities for natural surveillance and access control being 'designed in'?
- ❒ What security technologies are being considered? How do they reinforce and extend the impact of the school's security-focused design features?

13. Superior Indoor Air Quality

- ❒ Will the HVAC system being considered provide adequate ventilation, especially to the classrooms?
- ❒ Does the basic layout of the school keep operable windows and air intake vents away from sources of exhaust (e.g., cars and buses)?

14. Thermal Comfort

- ❒ Are windows and skylights being designed to minimize 'hot spots' caused by direct sunlight?
- ❒ Are temperature controls being considered for each classroom?

15. Visual Comfort

- ❒ Are the basic daylighting and electric lighting designs being developed so that they provide illumination in as uniform a manner as possible, using task or accent lighting as appropriate to meet specific needs?
- ❒ Are individual lighting designs being developed for individual room types? Do the designs vary, even within room type, depending on the amount of daylight the room will receive?
- ❒ Is the potential for glare being analyzed, and are the lighting/daylighting systems being designed to minimize it?
- ❒ Are the color and texture of wall, floor, and ceiling surfaces being taken into account in terms of their interaction with the lighting and their combined impact on the visual environment?

16. Water Efficiency

- ❒ Is water efficient landscaping part of the preliminary site design?
- ❒ Is irrigating only the athletic fields (not plants near buildings or parking lots) being considered?
- ❒ Are water reduction techniques being considered for school plumbing fixtures and equipment?
- ❒ Is capturing and reusing rainwater being considered?
- ❒ Are innovative wastewater treatment techniques being considered?

Questions to ask as the size and character of the project become more refined and as key building materials and systems – architectural, structural, mechanical, and electrical – become more clearly defined.

1. Acoustic Comfort

- ❒ How do the proposed materials and finishes (especially those used in the classrooms) help reduce sound reverberation?
- ❒ Have the classrooms been analyzed in terms of projected acoustic performance?
- ❒ Will the proposed heating/ventilating/air conditioning (HVAC) system for the classrooms create noise? If so, how will the noise be attenuated?

2. Commissioning

- ❒ Is appropriate design documentation being collected by or delivered to the commissioning agent?

3. Daylighting

- ❒ What daylighting strategies have been selected for the school (particularly the classrooms)?
- ❒ Are the classrooms receiving as much daylight as possible, while avoiding glare and unwanted heat gain?
- ❒ What types of glazing have been selected (for windows, clerestories, skylights, and/or roof monitors) and why are they more energy-efficient and cost-effective than competing alternatives?
- ❒ How will the daylighting and electric lighting systems interact?
- ❒ What analyses have been performed to optimize these interactions?
- ❒ Will the combined daylighting/electric lighting strategies reduce energy use and lower the school's operating costs over time?
- ❒ Has the possibility of reducing the number of light fixtures, or the number of lamps, in daylit rooms been investigated?

4. Energy Analysis Tools

- ❒ Have the energy analysis tool(s) selected for the project been used to project energy consumption at least once (preferably several times) during this phase of design?
- ❒ Do the results meet or exceed the facility's energy goal?

5. Energy Efficient Building Shell

- ❒ What basic wall, floor, and roof assemblies have been selected?
- ❒ What types of materials (glazing, shading, insulation, air barriers, structural materials) have been selected and why are they better, from an energy and life cycle cost perspective, than other alternatives?
- ❒ How have trade-offs (between amounts of window versus wall, between one type of glazing versus another, etc.) been analyzed, and how has the performance of the building shell as a whole been optimized?
- ❒ Have the impacts of thermal mass been factored in?
- ❒ Are light colored surfaces (particularly roofing) being used as a means to reduce heat gain?

6. Environmentally Preferable Materials and Products

- ❒ What types of environmentally preferable materials and products have been selected and where will they be used?
- ❒ Are all the selected materials and products low emitters of indoor air contaminants?

7. Environmentally Responsive Site Planning

- ❒ Does the final design preserve existing natural areas of the site?
- ❒ Does the design help control stormwater runoff?
- ❒ Does the design minimize areas covered with impervious surfaces (e.g., parking lots, paved walkways, etc.)?
- ❒ Do landscaping strategies (particularly tree planting) enhance the building's high performance features (i.e., by providing shade where it's needed but not blocking sunlight that's used for daylighting)?

8. High Performance HVAC

- ❒ What type of HVAC system has been selected for the school?
- ❒ Why is this system optimal from a comfort / energy performance perspective?
- ❒ Is it the best system from a life cycle cost perspective?
- ❒ How have the interactions between the HVAC system and other key building systems (lighting, daylighting, building shell) been analyzed and optimized?
- ❒ Has natural ventilation been considered? If so, have its potential impacts on HVAC performance been factored into the analysis process?
- ❒ Has the HVAC equipment been 'right sized' to meet predicted demand?
- ❒ What control system(s) have been selected and how will they influence performance?
- ❒ What level of control will individual teachers have over the heating, ventilating, and air conditioning of their classrooms?
- ❒ Is the entire system configured for ease of operation, maintenance, and repair?

9. High Performance Electric Lighting

- ❒ What electric lighting system(s) have been selected for the school and, in particular, for the classrooms?
- ❒ What are their energy and visual performance benefits?
- ❒ How do they interact with the daylighting strategies being implemented? How have these interactions been analyzed and optimized?
- ❒ What control system(s) have been selected and how will they effect performance?
- ❒ What level of control will teachers have over the lighting in their classrooms?

10. Life Cycle Cost Analysis

- ❒ Has the life cycle cost methodology selected for the project been used to compare and optimize alternate design strategies at least once (preferably several times) during this phase of the process?

11. Renewable Energy

- ❒ What renewable energy strategies have been selected and incorporated into the design?
- ❒ How much energy will they save?
- ❒ What are their life cycle cost benefits?
- ❒ How do they impact other building systems (lighting, electrical, HVAC, building shell)?
- ❒ What analysis has been performed to ensure that all of these systems will interact in a highly effective, integrated manner?

12. Safety and Security

- ❒ How have Crime Prevention through Environmental Design (CPTED) principles been applied during this phase of the process?
- ❒ Have opportunities for natural surveillance and access control been 'designed in'?
- ❒ What security technologies have been selected? How do they reinforce and extend the impact of the school's security-focused design features?

13. Superior Indoor Air Quality

- ❒ Will the HVAC system provide adequate ventilation, especially to the classrooms?
- ❒ Is the system designed to maintain the indoor relative humidity between 30% and 50%?
- ❒ Does the design provide local exhausts for restrooms, kitchens, science labs, janitor's closets, copy rooms, and vocational/industrial shop rooms?
- ❒ In large assembly areas, does the design include CO_2 sensors to monitor air quality?
- ❒ Are all the selected interior materials and products low emitters of indoor air contaminants?

14. Thermal Comfort

- ❒ Are HVAC distribution layouts designed to ensure that all areas of a room receive adequate ventilation?

15. Visual Comfort

- ❒ Do the daylighting and electric lighting system designs provide illumination in as uniform a manner as possible, using task or accent lighting as appropriate to meet specific needs?
- ❒ What tools have been used to model the interactions of both these systems in terms of their impacts on visual comfort?

- ❒ Have direct/indirect lighting fixtures been selected for general illumination in classrooms?
- ❒ What shading strategies (internal and external) have been selected?
- ❒ Have individual lighting designs been developed for individual room types? Do the designs vary, even within room type, depending on the amount of daylight the room will receive?
- ❒ Has the potential for glare been analyzed, and have the lighting/daylighting systems been designed to minimize it?
- ❒ Have the color and texture of wall, floor, and ceiling surfaces been taken into account in terms of their interaction with lighting and their combined impact on the visual environment?

16. Water Efficiency

- ❒ Has high efficiency irrigation technology been selected for athletic fields?
- ❒ Does the design use captured rainwater or recycled water for irrigation?
- ❒ Does the design include high efficiency equipment (dishwashers, laundry, cooling towers)?
- ❒ Does the design include low-flow showerheads and automatic lavatory faucet shut-off controls?
- ❒ Does the design include innovative wastewater treatment techniques?

Questions to ask once all the design elements are finalized and the documents (drawings and specifications) that will guide construction of the building are completed.

1. **Acoustic Comfort**
   - ❒ Are the walls of classrooms that are located next to noise sources designed for sound attenuation?
   - ❒ If rooftop HVAC equipment is being used, is it mounted on isolators to reduce sound transmission?

2. **Commissioning**
   - ❒ Have commissioning requirements been included in the construction documents?
   - ❒ Has a written commissioning plan been developed?

3. **Daylighting**
   - ❒ Will the construction details for daylighting components (the windows, lightshelves, roof monitors, skylights, shading devices, etc.) modify the performance of the system as a whole; i.e., will the required amount of daylight still reach the classrooms, will glare and heat gain be sufficiently controlled, etc? What will be the impact – on operating costs and on visual comfort – of any changes in performance?
   - ❒ Will the final construction details of other building components (for example, the color and reflectance of roofing materials adjacent to skylights or roof monitors) change the dynamics of the daylighting system and impact performance? What will be the impact – on operating costs and on visual comfort – of any changes in performance?

4. **Energy Analysis Tools**
   - ❒ Have the energy analysis tool(s) selected for the project been used to project energy consumption at least once during this phase of design?
   - ❒ Do the results meet or exceed the facility's energy goal?

5. **Energy Efficient Building Shell**
   - ❒ Do the final construction details for the wall, floor, and roof assemblies maintain the original design intent in terms of energy performance? (For example, do the assemblies allow insulation to be installed at the thickness originally specified, do air barriers cover all the areas they are supposed to, can areas – such as roof cavities – that need ventilation be adequately vented in the current configuration, etc.?)

6. **Environmentally Preferable Materials and Products**
   - ❒ Are the construction documents clear and explicit concerning the required environmental performance of the materials and products specified?
   - ❒ Do the documents include language requiring that a proposed material or product substitution be of equal or better quality in comparison to the specified product in terms of its environmental attributes?

7. **Environmentally Responsive Site Planning**
   - ❒ Have hardy, indigenous plants been specified in the landscaping plan?
   - ❒ Have exterior lights been designed to focus downward to reduce night sky light pollution?

8. **High Performance HVAC**
   - ❒ Do the equipment and products specified for the HVAC system continue to meet the design and performance goals previously established?
   - ❒ What analyses have been performed to ensure that the system is 'right sized' to meet expected demand?

9. **High Performance Electric Lighting**
   - ❒ What lamps, ballasts, and fixtures have been specified?
   - ❒ Why are they the best choices in terms of visual comfort, energy use, and long-term performance?
   - ❒ Will the system as finally configured and specified be easy to operate, maintain, and repair?
   - ❒ What is the impact of the system as finally configured on electricity use?

- ❒ Does the system as finally configured minimize waste heat? Has this been taken into account in sizing the cooling system?
- ❒ What controls have been specified? How will they help save energy and operating costs?
- ❒ What level of control will individual teachers have over the heating, ventilating, and air conditioning of their classrooms?

10. Life Cycle Cost Analysis

- ❒ Has the life cycle cost methodology selected for the project been used to compare and optimize alternative design strategies at least once during this phase of the process?

11. Renewable Energy

- ❒ Do the final construction details for renewable energy systems allow the systems to perform as designed? (For example, are solar systems installed so that they face the right direction, at the correct angle, to receive the right amount of sunlight? Does the final location of another building component – like a rooftop air conditioner – now prevent sunlight from reaching a solar collector? etc.)
- ❒ How are the renewable energy systems in their final configurations anticipated to perform from a life cycle standpoint?
- ❒ What warranty periods have been specified for the systems?

12. Safety and Security

- ❒ What type of exterior lighting has been specified and how will it improve security?
- ❒ Have durable materials been specified in critical areas such as entrances?
- ❒ What security technologies have been specified? How do they reinforce and enhance the building's security-focused design features?

13. Superior Indoor Air Quality

- ❒ Will the HVAC system as finally configured provide adequate ventilation, especially to the classrooms?
- ❒ Will the system maintain the indoor relative humidity between 30% and 50%?
- ❒ Are local exhausts provided for restrooms, kitchens, science labs, janitor's closets, copy rooms, and vocational/industrial shop rooms?
- ❒ Have CO_2 sensors been included in large assembly areas to monitor air quality?
- ❒ Are all the selected interior materials and products low emitters of indoor air contaminants?
- ❒ Have recessed grates or 'walk off' mats been installed at entrances to reduce the amount of dirt entering the building?

14. Thermal Comfort

- ❒ In their final configurations, do HVAC distribution layouts ensure that all areas of a room receive adequate ventilation?
- ❒ Have controls been installed to provide teachers with adequate control over the thermal comfort of their classrooms?

15. Visual Comfort

- ❒ In their final configurations, do the daylighting and electric lighting systems provide illumination as uniformly as possible, using task or accent lighting as appropriate to meet specific needs?
- ❒ Have direct/indirect lighting fixtures been specified for general illumination in classrooms?
- ❒ What shading strategies (internal and external) have been specified?
- ❒ Have the final configurations of other building components (such as the color of the walls, floor, or ceiling) been changed in ways that might influence system performance? Have the potential impacts of these changes on visual comfort been accounted for?

16. Water Efficiency

- ❒ Has high efficiency irrigation technology been specified for athletic fields?
- ❒ Has high efficiency equipment (dishwashers, laundry, cooling towers) been specified?
- ❒ Have low-flow showerheads and automatic lavatory faucet shut off controls been specified?
- ❒ Does the design include innovative wastewater treatment techniques?
- ❒ What will be the impact of all these water saving strategies – in their final configurations – on water use at the school? Will the results meet the school's water use goal?

Questions to ask as contractor bids are received to ensure that any proposed material or product substitutions do not adversely affect the school's performance goals.

1. **Acoustic Comfort**
   - ❒ Have any substitutions been proposed (alternate wall/floor/ceiling materials, different types of HVAC equipment) that could diminish acoustical quality, particularly in the classrooms?
   - ❒ If these substitutions are accepted, how will they affect overall acoustic comfort?

2. **Commissioning**
   - ❒ Has the commissioning plan been clearly described to potential bidders?

3. **Daylighting**
   - ❒ Have any substitutions been proposed (alternate glazing materials, different types of shading) that could influence the intended performance of the daylighting system?
   - ❒ If these substitutions are accepted, how will they affect system performance, visual comfort, and life cycle cost?

4. **Energy Analysis Tools**
   - ❒ Are the energy analysis tool(s) selected for the project being used to evaluate the energy consumption consequences of proposed material, product, or system substitutions?
   - ❒ Do the substitutions diminish the school's ability to meet its energy goal?

5. **Energy Efficient Building Shell**
   - ❒ Have any substitutions been proposed (alternate glazing materials, different types of insulation, alternate roofing products) that could influence the intended performance of the building shell?
   - ❒ If these substitutions are accepted, how will they affect the energy performance of the building and its life cycle cost?

6. **Environmentally Preferable Materials and Products**
   - ❒ Are all proposed substitutions equal to or better than the specified products in terms of their environmental attributes?
   - ❒ Are the substitutions also functionally equivalent to the specified products? (In other words, if they are accepted, they should not adversely affect the performance of the system or assembly in which they are used.)
   - ❒ What analyses have been performed to ensure that substitutions will not degrade environmental quality or system performance?

7. **Environmentally Responsive Site Planning**
   - ❒ Have any substitutions been proposed (different plants, alternate materials for parking lots or walkways, alternate exterior light fixtures) that could reduce the environmental quality of the site plan?
   - ❒ Will any of these substitutions diminish the building's performance? (For example, fewer trees may mean less shade and more heat gain in daylit classrooms.)
   - ❒ Have these impacts been analyzed? How will they affect the overall life cycle cost of the facility?

8. **High Performance HVAC**
   - ❒ Have any substitutions been proposed – alternate equipment, different types of controls, alternate delivery hardware (e.g., diffusers) – that could modify system performance?
   - ❒ After the substitutions, will the system still be 'right sized' to meet the demand (not over- or under-sized)?
   - ❒ If these substitutions are accepted, how will they affect the energy performance of the building and its life cycle cost?

9. **High Performance Electric Lighting**
   - ❒ Have any substitutions been proposed (alternate lamps, ballasts or controls) that could impact the intended performance of the electric lighting system?
   - ❒ Will these substitutions provide the same level of visual comfort consistent with design intent?
   - ❒ Will they introduce any additional waste heat to the space?

- ❒ Will they work correctly with the specified control system(s)?
- ❒ If these substitutions are accepted, how will they influence visual comfort, energy performance, and life cycle cost?

10. Life Cycle Cost Analysis

- ❒ Is the life cycle cost methodology selected for the project being used to analyze proposed material or product substitutions in terms of their impacts on overall performance and cost effectiveness?

11. Renewable Energy

- ❒ Have any substitutions been proposed – to specific systems or to the materials from which the systems are constructed – that could diminish intended performance?
- ❒ If these substitutions are accepted, how will they affect the energy performance and life cycle cost of the whole facility?

12. Safety and Security

- ❒ Have any material substitutions been proposed that could reduce the durability – and increase the vulnerability – of critical areas in the building (such as entrances)?
- ❒ Have any security technology substitutions been proposed?
- ❒ How well will the alternative technologies fit in with and complement the school's design-focused security measures?
- ❒ How will the substitute technologies interface with other controls systems in the school (e.g., those for the lighting and HVAC systems)?
- ❒ If substitutions are accepted, will they be as easy to operate, maintain, and repair as the originally specified products and systems?

13. Superior Indoor Air Quality

- ❒ Have any substitutions been proposed (alternate materials, a different ventilation system) that could impact indoor air quality?
- ❒ Are all substitute materials low emitters of indoor contaminants?
- ❒ Do substitute materials require different cleaning processes that may contaminate indoor air?
- ❒ Are substitutions being proposed for materials or assemblies which are designed to act as barriers to sources of indoor contaminants? Will the substitute materials/assemblies also act as effective barriers?

14. Thermal Comfort

- ❒ Have any substitutions been proposed (alternate glazing materials, different types of insulation, different types of ventilation hardware) that could affect thermal comfort, especially in the classrooms?
- ❒ If these substitutions are accepted, how will they influence the thermal comfort of students and teachers, the energy performance of the building, and its life cycle cost?

15. Visual Comfort

- ❒ Have any substitutions been proposed (alternate glazing materials, different types of lamps or light fixtures, alternate colors for walls, floors or ceilings) that could affect visual comfort, especially in the classrooms?
- ❒ If these substitutions are accepted, how will they influence the visual comfort of students and teachers, the energy performance of the building, and its life cycle cost?

16. Water Efficiency

- ❒ Have any substitutions been proposed (alternate plumbing fixtures, different types of landscape vegetation, an alternate irrigation system) that could reduce the school's water efficiency?
- ❒ If these substitutions are accepted, how will they affect water use and overall life cycle costs at the facility?

Questions to ask during the course of construction to ensure that the building is being built as designed, that it will meet its performance goals and that any proposed material or product substitutions do not adversely affect these goals.

1. **Acoustic Comfort**
   - ❒ Is the building being constructed as designed so as to achieve acoustic comfort?
   - ❒ Have any substitutions been proposed (alternate wall/floor/ceiling materials, different types of HVAC equipment) that could influence acoustical quality, particularly in the classrooms?
   - ❒ If these substitutions are accepted, how will they affect overall acoustic comfort?

2. **Commissioning**
   - ❒ Has the commissioning plan been implemented?
   - ❒ Has the functional performance of key systems been tested and verified?
   - ❒ Are the results documented in a commissioning report?
   - ❒ Have appropriate school staff been trained concerning proper operation of system equipment and controls?

3. **Daylighting**
   - ❒ Is the building, especially the classrooms, being constructed as designed to provide as much natural light as possible?
   - ❒ Have any substitutions been proposed (alternate glazing materials, different types of shading) that could diminish the intended performance of the daylighting system?
   - ❒ If these substitutions are accepted, how will they affect system performance, visual comfort, and life cycle cost?

4. **Energy Analysis Tools**
   - ❒ Are the energy analysis tool(s) selected for the project being used to evaluate the energy consumption consequences of proposed material, product, or system substitutions?
   - ❒ Do the substitutions impede the school's ability to meet its energy goal?

5. **Energy Efficient Building Shell**
   - ❒ Is the building shell being constructed as designed to achieve a high level of energy efficiency?
   - ❒ Have any substitutions been proposed – alternate glazing materials, different types of insulation, alternate roofing products – that could diminish the intended performance of the building shell?
   - ❒ If these substitutions are accepted, how will they affect the building's energy performance and its life cycle cost?

6. **Environmentally Preferable Materials and Products**
   - ❒ Are efforts being made to minimize construction waste?
   - ❒ Is some percentage of demolition and/or land clearing waste being salvaged or recycled?
   - ❒ Is the building being constructed using the environmentally preferable products specified?
   - ❒ Are all proposed substitutions equal to or better than the specified products in terms of their environmental attributes?
   - ❒ Are the substitutions also functionally equivalent to the specified products? (In other words, if they are accepted, they should not adversely affect the performance of the system or assembly in which they are used.)
   - ❒ What analyses have been performed to ensure that substitutions will not degrade environmental quality or system performance?

7. **Environmentally Responsive Site Planning**
   - ❒ Is the site being constructed and landscaped in the environmentally responsive way it was designed?
   - ❒ Have any substitutions been proposed (different plants, alternate materials for parking lots or walkways, alternate exterior light fixtures) that could diminish the environmental quality of the site plan?
   - ❒ Will any of these substitutions impact the performance of the building? (For example, fewer trees may mean less shade and more heat gain in daylit classrooms.)
   - ❒ Have these impacts been analyzed? How will they affect the overall life cycle cost of the facility?

8. High Performance HVAC

- ❒ Is the HVAC system being installed as designed, to achieve high performance?
- ❒ Have any substitutions been proposed – alternate equipment, different types of controls, alternate delivery hardware (e.g. diffusers) – that could modify system performance?
- ❒ After the substitutions, will the system still be 'right sized' to meet the demand (not over- or under-sized)?
- ❒ If these substitutions are accepted, how will they affect the building's energy performance and its life cycle cost?

9. High Performance Electric Lighting

- ❒ Is the electric lighting system being installed as designed, to achieve high performance?
- ❒ Have any substitutions been proposed (alternate lamps, ballasts or controls) that could diminish the intended performance of the electric lighting system?
- ❒ Will these substitutions provide the same level of visual comfort as the design calls for?
- ❒ Will they add any additional waste heat to the space?
- ❒ Will they work correctly with the specified control system(s)?
- ❒ If these substitutions are accepted, how will they affect visual comfort, energy performance, and life cycle cost?

10. Life Cycle Cost Analysis

- ❒ Is the life cycle cost methodology identified for the project being used to analyze proposed material or product substitutions in terms of their impacts on overall performance and cost effectiveness?

11. Renewable Energy

- ❒ Are the renewable energy systems being installed as designed to achieve high performance?
- ❒ Have any substitutions been proposed – to specific systems or to the materials from which the systems are constructed – that could diminish intended performance?
- ❒ If these substitutions are accepted, how will they impact the energy performance and life cycle cost of the whole facility?

12. Safety and Security

- ❒ Is the building being constructed as designed, to improve security?
- ❒ Are security technologies being installed as designed?
- ❒ Have any material substitutions been proposed that could reduce the durability – and increase the vulnerability – of critical areas in the building (like entrances)?
- ❒ Have any security technology substitutions been proposed?
- ❒ How well will the alternative technologies fit in with and complement the school's design-focused security measures?
- ❒ How will the substitute technologies interface with other control systems in the school (e.g., those for the lighting and HVAC systems)?
- ❒ If substitutions are accepted, will they be as easy to operate, maintain and repair as the originally specified products and systems?

13. Superior Indoor Air Quality

- ❒ Is the impact of the construction process on indoor air quality – for workers and, in the case of renovations, for students and teachers – being managed?
- ❒ Is the building being constructed as designed, to ensure healthful indoor air quality?
- ❒ Have any substitutions been proposed (alternate materials, a different ventilation system) that could adversely affect indoor air quality?
- ❒ Are all substitute materials low emitters of indoor contaminants?
- ❒ Do substitute materials require different cleaning processes that may contaminate indoor air?
- ❒ Are substitutions being proposed for materials or assemblies that are designed to serve as barriers to sources of indoor contaminants? Will the substitute materials/assemblies also act as effective barriers?
- ❒ Is there a plan to 'flush out' the facility for at least 72 hours after construction and before occupancy?

14. Thermal Comfort

- ❒ Is the building being constructed as designed, for optimal thermal comfort, especially in the classrooms?
- ❒ Have any substitutions been proposed – alternate glazing materials, different types of insulation, different types of ventilation hardware – that could affect thermal comfort, especially in the classrooms?
- ❒ If these substitutions are accepted, how will they affect the thermal comfort of students and teachers, the energy performance of the building, and its life cycle cost?

15. Visual Comfort

- ❒ Is the building being constructed as designed, to enhance visual comfort, especially in the classrooms?
- ❒ Have any substitutions been proposed (alternate glazing materials, different types of lamps or light fixtures, alternate colors for walls, floors or ceilings) that could affect visual comfort, especially in the classrooms?
- ❒ If these substitutions are accepted, how will they influence the visual comfort of students and teachers, the energy performance of the building, and its life cycle cost?

16. Water Efficiency

- ❒ Are the building and grounds being constructed as designed, to conserve water?
- ❒ Have any substitutions been proposed (alternate plumbing fixtures, different types of landscape vegetation, an alternate irrigation system) that could reduce the water efficiency of the school?
- ❒ If these substitutions are accepted, how will they affect water use and overall life cycle costs at the facility?

Introducing the Building Blocks of High Performance School Buildings

Section 3 of the *Resource & Strategy Guide* provides an overview of the key components of a high performance school building. Information is presented in a series of 2-page *Building Block* 'briefs', each covering one of the following building components or attributes:

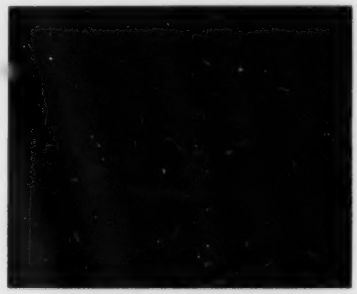
Acoustic Comfort
Commissioning
Daylighting
Energy Analysis Tools
Energy Efficient Building Shell
Environmentally Preferable Materials and Products
Environmentally Responsive Site Planning
High Performance HVAC
High Performance Electric Lighting
Life Cycle Cost Analysis
Renewable Energy
Safety and Security
Superior Indoor Air Quality
Thermal Comfort
Visual Comfort
Water Efficiency

Each brief presents a quick overview of the key aspects of the particular component or system:

What it is;
Why it's important for ensuring high performance;
How it can be incorporated into a new school building;
How it impacts other building components and systems.

The discussions are purposely short, and are only intended to provide an introduction to key issues and concepts. Further information can be found by accessing the resources listed at the end of each *Building Block*.

The *Building Blocks* are particularly valuable when used in conjunction with the *Process Guide* (Section 2 of the *Resource & Strategy Guide*). As questions from the *Process Guide* are analyzed and discussed over the successive phases of the school development process, the *Building Blocks* section can be consulted for additional information and for access to in-depth resources on a given topic.



A recent study of large, urban schools in Virginia has found a strong relationship between building condition and student performance. In substandard buildings, student achievement was as much as 11 percentile points lower than in above-standard facilities.

Source: Hines, Eric (1996) Building Condition and Student Achievement and Behavior. Unpublished doctoral dissertation. Blacksburg, VA: Virginia Polytechnic Institute and State University

"High performance school buildings – facilities that integrate the latest design strategies and building technologies to create the highest quality learning and teaching environments – are achievable now. We're seeing examples all across the country. With the tools and systems available today, there's no reason that every new school can't be a high achiever when it comes to building performance."

– Deane Evans, FAIA
Vice Chair, Sustainable Buildings Industry Council

What

Parents, students, teachers, and administrators across the country are increasingly concerned that classroom acoustics are inadequate for proper learning. Noise from outside the school (vehicular traffic and aircraft flyover), hallways (foot traffic and conversation), other classrooms (amplified sound systems and inadequate sound attenuation), mechanical equipment (compressors, boilers and ventilation systems), and even sound from within the classroom itself (reverberation) can all hamper students' concentration. The message has even reached the Access Board, the organization that supports implementation of the Americans with Disabilities Act, which has received complaints concerning the effects of bad acoustics on hearing-impaired students.

A high performance school should address these potential problems and ensure a superior acoustical environment by:

- Reducing sound reverberation time inside the classroom;
- Limiting transmission of noise from outside the classroom; and
- Minimizing background noise from the building's heating, ventilating, and air conditioning system.

Why

Trying to hear in a poor acoustical environment is like trying to read in a room with the lights off: stress increases, concentration decreases, and learning is impaired. This is especially true for younger students (the ability to sort meaningful signals from noise is not fully developed until children reach their teens), those for whom English is a second language, and those with hearing impairments. Although little consideration has historically been given to acoustic design in classrooms – as opposed to lighting and ventilation – this situation is beginning to change. The information and tools needed to design classrooms for high acoustical performance now exist. They can be used to ensure that any newly constructed classroom provides an acoustic environment that positively enhances the learning experience for students and teachers.

Sterling Montessori Academy – Morrisville, NC

The roof monitors that bring daylight into the classrooms of this 200-student elementary school in a Raleigh suburb provide an added benefit: improved acoustics. The large, open space under the monitors, plus the baffles used to control glare, help damp sound throughout the classroom. The result is an improved environment for teaching and learning.

When asked to name the best feature of her new classroom, a teacher at the school unhesitatingly responded by pointing up the great acoustics, surprising the architects who had expected the substantial amount of daylight to be the answer. Happily, the roof monitors provide both.

How

Reduce sound reverberation time in classrooms to 0.5 seconds in 500, 1000, 2000 and 4000 Hz Octave Bands

- Configure classrooms to damp rather than magnify sound reverberation.
- Specify sound absorbing materials (especially on exposed surfaces) to damp reverberation.

Limit transmission of noise from outside the classroom

- Design high Sound Transmission Class (STC) walls between...
  - Classrooms adjacent to laboratories (STC-50);
  - Classrooms adjacent to music practice or mechanical equipment rooms (STC-55).
- Design exterior walls, windows, and roofs such that noise transmission (except for intermittent noise such as airplane flyovers) is reduced to the same levels as background noise inside the classroom (i.e., RC 30 – 35).

Minimize background noise from the building's heating, ventilating, and air conditioning system.

- Design the system to achieve the following RC levels, based on the Room Criterion method explained in the ASHRAE 1999 Applications Handbook:
  - Ideal RC-25N
  - Acceptable RC-30N
  - Maximum RC-35N
- Avoid locating mechanical equipment rooms next to classrooms.
- Recognize that sound control is more difficult in unducted rooftop or through-the-wall units than in central air handling systems.
- If using ducted rooftop units, ensure that they are mounted on spring isolators.
- Consider using larger ducts with lower air flow speeds (1000 feet per minute maximum).
- Select diffusers with low noise ratings (NC-20 to NC-23).

Impact on Other Systems and Technologies

When classroom ceilings are designed to optimize daylighting, suspended acoustical ceilings are often eliminated and the exposed surfaces are painted with highly reflective paint to throw daylight well into the classroom. The sound absorption value lost by the absence of the suspended ceiling must be replaced in other ways to prevent the classroom from becoming highly reverberant.

In situations where skylights or roof monitors are used, parts of the acoustical ceiling are also removed. However, the open space under the skylights or monitors can also dampen reverberation and may compensate for the lost portions of acoustical ceiling.

Resources

- *1999 Applications Handbook*, American Society of Heating, Refrigerating and Air Conditioning Engineers (www.ashrae.org)
- Acoustical Society of America (http://asa.aip.org)
- American Speech-Hearing-Language Association (www.asha.org/index.htm)
- *Architectural Graphic Standards*, Tenth Edition, Ramsey/Sleeper, The American Institute of Architects, pages 63-70.
- Classroom Acoustics Coalition (www.nonoise.org/quietnet/qc/index.htm)
- Guidelines for Classroom Acoustics in New Construction (www.nonoise.org/quietnet/qc/workshop/dec97shp/guide.htm)
- Institute of Noise Control Engineering (http://users.aol.com/inceusa/ince.html)
- National Council of Acoustical Consultants (www.ncac.com)

What

Building commissioning is the systematic process of ensuring and documenting that all building systems perform in accordance with design intent, and that they meet the owner's operational needs. The key components of a comprehensive building commissioning plan are:

- Documenting the design intent and operating protocols for all building systems;
- Verifying in-place system performance through well-documented testing and measurement;
- Preparing comprehensive operation and maintenance manuals, coupled with appropriate training of building operations staff; and
- Monitoring system performance on an ongoing basis.

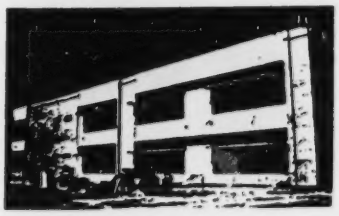
Properly implemented, such a plan will ensure that a new school starts its life cycle at the highest performance level possible.

(Note: Building commissioning is not yet common practice. Therefore, it's important to define areas of responsibility in the process; particularly who will bear the cost of correcting conditions that do not meet specifications. This should be clearly spelled out at the very beginning.)

Why

A high performance school's key systems should be designed to function interactively in ways that create a healthy, productive, environmentally efficient, and cost-effective environment for teaching and learning. A robust commissioning process will ensure that these systems actually function as designed and that they meet the goals of the school's students, teachers, and administrators.

In many ways, commissioning is similar to a 'test run' or 'systems check.' It tests, verifies, and fine-tunes the performance of key building systems, so that the highest levels of performance are achieved. Correctly implemented, commissioning should improve the building delivery process, increase systems reliability, improve energy performance, ensure good indoor environmental quality, and improve facility operations and maintenance.



Clackamas High School – Clackamas County, OR

This 1,800 student school near Portland is one of the first in the country to incorporate whole building commissioning (HVAC system, electrical system, and controls) into the overall design/delivery process.

Heinz Rudolf of Boora Architects notes that, "This school has been designed to operate at a high level of efficiency. Commissioning will ensure that it does so." Boora and the owner retained an independent company, Interface Engineering, to act as the commissioning agent. Completion is scheduled for Summer 2001.

How

There are three basic types of building commissioning. The more comprehensive and inclusive the program, the greater the impact on school performance.

- Whole Building (HVAC system, controls, and electrical system);
- HVAC System and Automated Controls Only; and
- Electrical System Only.

(Note: 'Total Building Commissioning' protocols, which take into account additional components such as finishes and materials, are currently under development but not yet available for use in schools.)

Whichever type of commissioning approach is chosen, consider implementing the following procedures:

- Engage a commissioning agent at or before the design phase of the project;
- Collect and review design intent documentation;
- Ensure that commissioning requirements are included in the construction documents;
- Develop and utilize a written commissioning plan;
- Test and verify installation and functional performance of systems; and
- Document results and develop a commissioning report.

Impact on Other Systems and Technologies

Commissioning strongly influences the final design and size of a school's HVAC, electrical, and control systems. Properly implemented, commissioning helps ensure that these systems are 'right sized' and that they function at the optimal levels of efficiency and cost effectiveness.

Resources

- Building Commissioning Association – www.bcxa.org
- *Building Commissioning Handbook*, Association of Higher Education Facilities Officers – www.appa.org
- *Building Commissioning Guide*, Federal Energy Management Program – www.eren.gov/FEMP
- Energy Smart Schools Program, U.S. Department of Energy – www.eren.doe.gov/energysmartschools
- *Model Commissioning Plan and Guide Specifications*, Portland Energy Conservation Inc. – www.peci.org
- *Procedural Standards for Building Systems Commissioning*, National Environmental Balancing Bureau – www.nebb.org
- *The HVAC Commissioning Process*, ASHRAE Guideline 1-1996 – www.ashrae.org
- *National Clearinghouse for Educational Facilities* – www.edfacilities.org/ir/hottopics.cfm

Building Block #3 — Daylighting

What

Daylighting is the controlled admission of natural light into a space through windows, skylights, or roof monitors. A high performance school should use as much natural daylight as possible (especially in classrooms) while avoiding excessive heat loss, heat gain, and glare.

Why

Access to natural light may be one of the most important attributes of a high performance school. Daylight is the highest quality light source for visual tasks, as it enhances the color and appearance of objects. Studies clearly indicate that *daylighting can enhance student performance* (see resources). Views from windows also provide a connection with the natural world and promote healthy vision by allowing frequent changes in focal distance.

Daylighting can also save a school money. Properly designed systems can substantially reduce the need for electric lighting, which can account for 35 to 50 percent of a school's electrical energy consumption. An added benefit: waste heat from the lighting system is also reduced, which in turn reduces demand on the school's cooling equipment. These savings can be as much as 10 to 20 percent of a school's cooling energy usage. It's also worth noting that daylight provides these savings during the day, when demand for electric power is at its peak and rates are at their highest.

How

- Use a daylighting analysis tool to help guide the design process.
- Design windows to allow daylight to penetrate as far as possible into a room. Consider using light shelves (solid horizontal elements placed above eye level, but below the top of the window) to reflect daylight deep into a room.
- Design for diffuse, uniform daylight throughout the room.
- Consider skylights (horizontal glazing), roof monitors (vertical glazing), light from two sides, and/or clerestory windows.
- Avoid direct-beam sunlight.
- Avoid glare.
- Consider interior (shades, louvers, or blinds) and exterior (overhangs, trees) strategies to control glare and filter daylight.

Dena Boer Elementary School – Salida, CA

Skylights are used to distribute natural daylight to the classrooms, library, multipurpose room, and offices of this 800-student, K-5 school near Modesto, California. Louvers installed in the skylight wells help control daylight levels and can be used to darken rooms when necessary. Classroom windows provide additional daylight and are protected by deep overhangs that control direct sunlight and glare.

All of these 'extras' were provided within the standard construction budget for the school, which was completed in 1997. The key was making daylighting a priority for the school and then shifting funds from elsewhere in the budget to pay for it.

The extra sunlight has proven to be very popular. School Principal Rick Bartkowski observed that "The skylights create an open, bright work environment. We just seem to have more room. Visitors say it sure is a pleasant place to come into."

How (*continued*)

- Design room layouts that take advantage of daylight. Consider sloped ceilings and/or light colored ceiling surfaces to help reflect daylight within the room.
- Integrate daylighting with the electric lighting system. Provide controls that turn off lights when sufficient daylight exists. Consider dimming controls that continuously adjust lighting levels in response to daylight conditions.

Impact on Other Systems and Technologies

Daylighting strategies should interact strongly with a school's lighting and HVAC systems. Properly designed daylighting systems will reduce the need for electric light, thus lowering overall electricity usage. Less electric light also means less waste heat from the lighting system, reducing the need for cooling. Both of these strategies improve the school's bottom line by substantially reducing overall energy costs. Operable windows and skylights can also be opened to provide natural ventilation when outdoor conditions permit, further reducing the need for mechanical heating and/or cooling.

Resources

- *Analysis of the Performance of Students in Daylit Schools*, M. Nicklas and G. Bailey, Proceedings of the 1997 Annual Conference, American Solar Energy Society
- *Daylighting in Schools*, Heschong Mahone Group, Pacific Gas and Electric Company on behalf of the California Board for Energy Efficiency Third Party Program, August 1999
- *Effects of School Lighting on Physical Development and School Performance – A Case of Daylight Robbery*, W. Hathaway, Policy and Planning Branch, Alberta Education, January 1992
- Illuminating Engineering Society of North America – www.iesna.org
- Lawrence Berkeley National Laboratory – www.lbl.gov
- Lighting Research Center, Rensselaer Polytechnic Institute – www.lrc.rpi.edu
- Skylighting Guidelines – www.energydesignresources.com

Building Block #4 Energy Analysis Tools

What

Energy Analysis Tools are computer programs designed to predict a building's annual (and in some cases, even hourly) energy consumption. They can be used to evaluate the energy impacts of various design alternatives and, in particular, to quantify and compare the contributions of various low-energy strategies (e.g., higher insulation levels, better glazing, increased thermal mass, etc.) in terms of their influence on overall building performance. Combined with accurate cost estimates, energy analysis programs can help create a high performance school that is optimized in terms of its overall energy performance.

The design team for a high performance school should begin using an energy analysis tool(s) at the outset of the design process (ideally during pre-design, when sustainable building strategies can be integrated at lowest possible cost) and continue through the bidding/negotiation phase.

Why

Reducing energy consumption in a cost-effective manner is good for both the environment and the school district's bottom line. Doing so requires the ability to quickly compare and contrast a variety of alternate design strategies so that the optimal approach can be selected. Fast, accurate estimates of building energy performance – which the current generation of energy analysis tools can provide – are critical to this process.

How

A wide number of energy analysis tools are currently available, some appropriate for the early stages of a project, others developed with the later phases in mind. The following list contains a sampling of tools for both time periods. Sources of additional tools can be found in the Resources section below.

Architectural Design Tools – to be used primarily during the programming, schematic design, and design development phases of a project.

- *ENERGY-10,* Sustainable Buildings Industry Council – www.sbicouncil.org
- Building Design Advisor, Lawrence Berkeley National Laboratory – gundog.lbl.gov
- Energy Scheming, Iris Communications – www.oikos.com/esb/37/scheming.html

Dillard Drive Middle School
Wake County, NC

DOE 2, an energy analysis tool developed by the Lawrence Berkeley National Laboratory for the U.S. Department of Energy, was used to 'design in' superior energy performance at this 1,000-student middle school near Raleigh, North Carolina.

The tool helped the design team fine-tune the interactive performance of the school's key components – the building shell, the lighting and daylighting systems, and the heating/ventilating/air conditioning (HVAC) equipment – to generate the most cost-effective, energy efficient design possible for the facility as a whole. The result is a daylit school that uses advanced lighting controls, fiber optic networking, automatic environmental controls, and an energy management system to provide a high quality learning environment, while reducing energy consumption.

How *(continued)*

Load Calculation and HVAC Sizing – to be used primarily during the design development and construction documents phases of a project.

- HAP, Carrier Corporation – www.carrier.com
- TRACE, Trane Corporation – www.trane.com
- Softdesk Energy, Pacific Northwest National Laboratory – www.pnl.gov
- DOE-2, Lawrence Berkeley National Laboratory – gundog.lbl.gov
- BLAST, University of Illinois – www.bso.uiuc.edu
- VisualDOE, Eley Associates – www.eley.com
- EnergyPlus, Lawrence Berkeley National Laboratory – gundog.lbl.gov

Energy performance analyses using one or a combination of these tools should be conducted during each of the following design phases:

- Programming
- Schematic Design
- Design Development
- Construction Documents
- Bidding and Negotiation

Impact on Other Systems and Technologies

Energy analysis tools allow interactions between all of a school's key systems (building shell, windows, lighting, space conditioning) to be analyzed, compared, and optimized for energy performance. This can save a school money on initial construction costs as well as on long-term operating expenses.

For example, a school that combines daylighting strategies and highly efficient electric lighting in its classrooms will require less electricity to illuminate those classrooms – a long-term operating savings. In addition, because the rooms take advantage of daylight and use high efficiency lamps, fewer overall light fixtures may be needed in order to achieve a high quality visual environment. This results in an immediate savings on initial costs. Finally, highly efficient lighting – and, potentially, fewer light fixtures – will result in less waste heat in each classroom. This, in turn, allows the cooling system for the classrooms to be smaller, yielding additional up-front savings.

Resources

- *ASHRAE Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings,* American Society of Heating, Refrigerating and Air Conditioning Engineers – www.ashrae.org
- *Energy Analysis Tools Directory,* U.S. Department of Energy, Office of Building Technology, State & Community Programs – www.eren.doe.gov/buildings/tools_directory
- *Energy Star Benchmarking Tool for Schools,* U.S. Environmental Protection Agency – www.epa.gov/buildings/label

Building Block #5 Energy Efficient Building Shell

What

The building shell (walls, roofs, floors, and windows) of a high performance school should enhance energy efficiency without compromising durability, maintainability, or acoustic, thermal or visual comfort. An energy efficient building shell is one that integrates and optimizes insulation levels, glazing, shading, thermal mass, air leakage control, and light-colored exterior surfaces.

Why

An energy-efficient building shell will reduce a school's overall operating expenses while easing the strain on the environment. Many of the techniques employed – high performance glazing, shading devices, light-colored surfaces – are easily accessible to students and can be used as instructional aids.

How

The key to optimizing the building shell is an integrated approach to design that considers how all the components of the shell interact with one another and with the building's lighting and heating/ventilating/air conditioning (HVAC) systems. Tools to analyze these interactions are readily available and can be used to create the optimal building shell based on total system performance.

As part of an integrated approach, the following actions, specific to the building shell, should be considered.

Glazing

- Specify glazing that represents the best combination of insulating value, daylight transmittance, and solar heat gain coefficient for its specific application and local climatic conditions.

Shading

- Consider exterior shading devices to reduce solar heat gain and minimize glare.

Thermal Mass (high mass materials, like concrete or brick, for walls and floors)

- Use the building's thermal mass to store heat and temper heat transfer.
- Consider adding thermal mass to increase the storage capacity and energy efficiency of the school.

Oquirrh Hills Elementary School – Kearns, Utah

Well-insulated metal stud and brick veneer walls, a light colored roof with R-30 rigid insulation, and windows with low-e glass all contribute to the superior energy performance of this elementary school near Salt Lake City.

The school, completed in 1996, replaced a previous facility that had been destroyed by fire. The new building saves roughly $22,000 per year in operating costs compared to its predecessor – a result of careful design coupled with high performance systems and an energy efficient building shell.

Based on its experience with Oquirrh Hills, the Jordan School District has embraced high performance as a procurement goal and has gone on to build six more energy-efficient schools.

"High performance, energy smart school design means going 'beyond code'...cost effectively That's just what the architects did at Oquirrh Hills," notes Duane Devey, Director of Energy and Utility Resources for Jordan School District.

How *(continued)*

Air Leakage Control

- Consider air retarder systems (also referred to as 'air infiltration barriers') as a means of improving energy performance and reducing potential water damage in walls and roofs.

Light-Colored Surfaces

- Consider using light-colored materials for walls and roofs in order to reflect, rather than absorb, solar energy.

Impact on Other Systems and Technologies

The building shell strongly impacts the performance of a school's HVAC and lighting systems. The amount of heat the building shell lets in or out determines how much heating or cooling the HVAC system must provide. The more efficient the building shell, the less the HVAC system will have to work and the smaller (and less expensive) it can be.

Likewise, if the window system is designed to maximize natural daylight, less electric light will be needed. This will reduce the school's electricity costs. In addition, the school's need for cooling will decrease. This is because electric lights generate heat. In schools where less electric light is used, less waste heat will be created, resulting in a reduced demand for cooling and even more HVAC system savings.

Resources

- EPA Energy Star Program – www.epa.gov/energystar
- Federal Energy Management Program – www.eren.doe.gov/femp/femp.html
- U.S. Department of Energy – www.eren.gov
- Whole Building Design Guide – www.wbdg.org

Building Block #6

Environmentally Preferable Materials & Products

What

Building materials can have a significant impact on the environment and on human health. To the maximum extent possible, a high performance school should be constructed of durable, non-toxic materials that are high in recycled content and are themselves easily recycled. Preference should be given to locally manufactured materials and those derived from sustainable-yield processes. The school itself should be designed to facilitate recycling and, to the extent possible, waste should be minimized during construction.

Why

Some building materials contain toxic substances that can harm workers during construction, and may also be harmful to students and teachers after occupancy. In addition, the mining, harvesting, and production of certain building materials can pollute our air and water, destroy habitats, and deplete natural resources. Transporting building products long distances also contributes to pollution and energy waste.

Careful selection of materials can reduce or eliminate these problems, resulting in a school that not only helps the environment, but also contributes to the health and well-being of its occupants. Many of the materials selected – particularly those with recycled content – can serve as the basis for lessons on ecology and the environment, as can areas within the building designed for on-site recycling.

How

Design to Facilitate Recycling

- 'Design in' an area within the building dedicated to separating, collecting, and storing materials for recycling, including paper, glass, plastics, and metals.
- Consider where and how materials will be collected and brought to the central area and allow space for easy collection and transport.

Reduce the Amount of Construction Waste that Goes to Landfill

- During construction, develop and implement a management plan for sorting and recycling construction waste.
- Consider a goal of recycling or salvaging 50% (by weight) of total construction, demolition, or land-clearing waste.

Ocean Park School – Santa Monica, CA

Certified sustainable-yield lumber, formaldehyde-free casework and insulation, non-VOC sealants, and recycled plastic bathroom partitions were all incorporated into this 45,000 square foot, K-8 school in Santa Monica.

"It's not difficult to make our schools healthier and more environmentally responsible, but you have to start early in the process by 'designing in' high performance, non-toxic materials and products from the very beginning," says Betsey Dougherty, lead architect for the project.

How *(continued)*

Specify Materials and Products that are Environmentally Efficient

- Specify materials, especially timber, harvested on a sustainable-yield basis.
- Consider a goal of having 50% of the school's wood-based materials certified in accordance with the Forest Stewardship Guidelines for wood building components.
- Give preference to locally manufactured materials and products, which stimulate the local economy and reduce transport distances.
- Consider specifying salvaged or refurbished materials, as appropriate.

Maximize Recycled Content of All New Materials

- Use EPA-designated recycled content products to the maximum practicable extent.
- Within an acceptable category of product, use materials and assemblies with the highest available percentage of post-consumer or post-industrial recycled content.
- Consider a goal of having 25% of the school's building materials contain a weighted average of 20% post-consumer or 40% post-industrial recycled content.

Eliminate Materials that Pollute or are Toxic During Manufacture, Use or Reuse

- Within an acceptable category of product, use materials or assemblies with the lowest levels of volatile organic compounds (VOCs).
- Eliminate the use of chlorofluorocarbons (CFCs) and hydrochlorofluorcarbons (HCFCs) as refrigerants in all HVAC systems.
- Evaluate the potential impact of specified materials on the indoor air quality of the school (see Issue Brief #13 "Superior Indoor Air Quality").

Impact on Other Systems and Technologies

Building products and materials will impact the indoor air, acoustic, and visual quality of a school. They can also affect operation and maintenance procedures. When new materials are used, new procedures may be required for their maintenance and upkeep. These new procedures should not be more complicated, costly, or time consuming than those associated with standard products, but they will be new, and so maintenance staff will require some training to implement them effectively.

Resources

- BEES (Building for Environmental and Economic Sustainability), National Institute of Standards and Technology – www.bfrl.nist.gov
- Center for Resourceful Building Technology – www.crbt.org
- Certified Forest Products Council – www.certifiedwood.org
- Construction and Demolition Waste Recycling Information, California Integrated Waste Management Board – www.ciwmb.ca.gov
- *Environmental Building News* – www.buildinggreen.com
- *EPA Comprehensive Guide for Procurement of Products Containing Recovered Materials*, U.S. Environmental Protection Agency – www.epa.gov/epaoswer
- Forest Stewardship Council – www.fscoax.org
- Green Seal – www.greenseal.org
- National Park Service Sustainable Design and Construction Database – www.nps.gov/dsc/dsgncnstr
- Rainforest Alliance – www.rainforest-alliance.org
- Recycled Content Product Database, California Integrated Waste Management Board – www.ciwmb.ca.gov/rcp
- Scientific Certification Systems – www.scs1.com
- *Sustainable Building Sourcebook* – www.greenbuilder.com/sourcebook
- *The Environmental Resource Guide*, John Wiley & Sons – www.wiley.com
- *The Green Building Resource Guide* – www.greenguide.com
- *The Resources for Environmental Design Index (REDI)* – www.oikos.com

Building Block #7

Environmentally Responsive Site Planning

What

A high performance school should be located on a high performance site; one that helps the school function at peak efficiency, minimizes adverse impacts on the local environment, and serves as an amenity for the surrounding community. A high performance site should be planned to conserve existing natural areas and restore damaged ones, minimize stormwater runoff and control erosion, enhance the school's high performance features, reduce 'heat islands', and minimize light pollution.

Why

A high performance site is good for the local and regional environment. It can also help reduce a school's operating costs by enhancing, rather than inhibiting, the high performance features of a facility (e.g., energy conservation, water conservation, renewable energy, safety and security, etc.).

A well-planned, high performance site can also be an exciting natural laboratory for students.

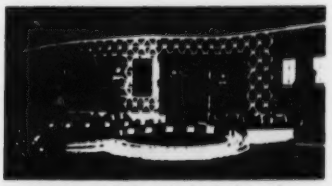
How

Conserve Existing Natural Areas and Restore Damaged Ones

- Preserve local vegetation in place, especially mature trees.
- Reduce parking and building 'footprints.'
- Landscape with indigenous plants to restore damaged areas of the site.

Minimize Stormwater Runoff and Control Erosion

- Design so that, at a minimum, there is no net increase in stormwater runoff from the site after the school is built.
- Reduce impervious surfaces (such as parking lots, paved paths, etc.) that contribute to runoff.
- Maximize on-site stormwater infiltration.
- Consider providing for on-site stormwater retention.
- Use vegetation to keep soil in place.
- Consider anti-erosion grading and stabilization techniques.
- Minimize stormwater runoff during construction.



Brunswick High School – Brunswick, ME

The site plan for this 1200-student school north of Portland is a model of environmental responsiveness. Thirty percent of the total site area has been retained in its natural state, including five acres of blueberry fields. Trees and shrubs in the preserved area have been identified and tagged, creating a mini-arboretum that is used for nature studies.

Water runoff is also strictly controlled. Because the site is in an ecologically sensitive coastal watershed, codes require that runoff after construction be no greater than it was before development. To meet this requirement, the architects created a water treatment plant right on the school grounds. The water detention area, holding tank, wetlands and ponds treat the water effectively and serve as a first rate environmental education lab for students at the same time.

How *(continued)*

Use the Site to Enhance the School's High Performance Features

- Orient the building on the site to take advantage of the sun (usually along an east-west access to maximize southern exposure), the prevailing breezes, shade trees and any landforms that might reduce the building's energy use, increase its access to natural daylight, enhance its acoustical environment, and/or improve its security.

Reduce Heat Islands (developed areas, such as parking lots, that are much hotter than surrounding, undeveloped areas)

- Use landscape elements (preferably existing trees and vegetation) to shade roads, walkways, and parking lots.
- Consider using light colored materials for the school's roof to reflect, rather than absorb, sunlight.

Reduce Light Pollution

- Design site lighting so as to minimize contribution to nighttime skyglow.
- Consider outdoor lights with covered tops so that the light shines down, rather than up into the nighttime sky.

Impact on Other Systems and Technologies

Site conditions impact virtually every system in a building. A well-integrated design and site planning process will ensure that the site reinforces the building and vice versa, and that both components operate at peak levels of performance.

Resources

- Center of Excellence for Sustainable Development, U.S. Department of Energy – www.sustainable.gov
- Cool Roofing Materials Database, Lawrence Berkeley National Laboratory – eetd.lbl.gov/Cool Roofs
- Energy Star Roof Products, U.S. Environmental Protection Agency – www.epa.gov/appdstar/roofing
- International Dark Sky Association – www.darksky.org
- Soil and Water Conservation Society – www.swcs.org
- Storm Water Management for Construction Activities, U.S. Environmental Protection Agency – www.epa.gov
- Sustainable Site Design, National Park Service – www.nps.gov

Building Block #8 High Performance Heating Ventilating and Air Conditioning (HVAC)

What

A school's HVAC system provides the heating, ventilating, and air conditioning necessary for the comfort and well being of students, teachers, administrators, and visitors. To ensure peak operating efficiency, the HVAC system in a high performance school should:

- Use high efficiency equipment;
- Be 'right sized' for the estimated demands of the facility;
- Include controls that boost system performance.

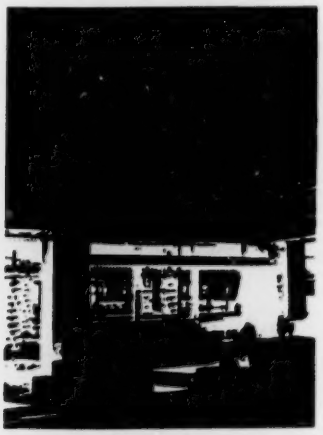
Why

The HVAC system is one of the largest energy consumers in a school. Even modest improvements in system efficiency can yield relatively large savings in a school's operating budget. With the highly efficient systems available today (and the sophisticated analysis tools that can be used to select and size them), every school HVAC system can be designed to the highest levels of performance.

Various parts of the HVAC system (especially controls placed inside the classroom) can be used as instructional aids.

How

The key to optimizing HVAC system performance is an integrated approach to design that considers the building as a interactive whole, rather than as an assembly of individual systems. For example, the benefits of an energy efficient building shell may be wasted if the HVAC equipment is not sized to take advantage of it. Based on rule-of-thumb sizing calculations, an oversized system will not only cost more, it will be too large to run at peak efficiency and will, in effect, waste energy every time it turns on. An integrated approach, one based on an accurate estimate of the impact of the high efficiency building shell, will allow the HVAC system to be sized for optimum performance. The resulting system will cost less to purchase, will use less energy, and will run more efficiently over time.



Newport Coast Elementary School
Newport Coast, CA

After careful analysis of first costs versus performance benefits, high efficiency heat pumps – one for each classroom – were selected for this 400-700 student school south of Los Angeles. The equipment was designed and sized to work well with the natural ventilation systems built into each classroom. Controls for both systems are provided in each classroom so that teachers can maintain optimal conditions at all times.

How *(continued)*

As part of an integrated approach, the following actions (specific to HVAC systems) should be considered.

Use High Efficiency Equipment

- Specify non-CFC (chlorofluorocarbon) – based refrigerants for systems using large chillers.
- Specify equipment that meets or exceeds the U.S. Department of Energy's *Energy Conservation Voluntary Performance Standards for New Buildings.*
- Use ENERGY STAR®-approved products.
- Consider recovery systems that pre-heat or pre-cool incoming ventilation air.
- Consider 'economizer cycles' for small, packaged systems.
- In hot, dry climates, consider evaporative cooling.
- Investigate the potential for on-site cogeneration.

'Right-Size' the System

- Consider standard HVAC sizing safety factors as upper limits.
- Apply any safety factors to a reasonable base condition for the building (i.e., not the hottest or coldest day of the year with maximum attendance; not the most temperate day of the year with the school half full).
- Select systems that operate well under part-load conditions.

Incorporate Controls that will Boost System Performance

- Consider integrated building management systems that control HVAC, lighting, outside air ventilation, water heating, and building security.
- Consider individual HVAC controls for each classroom.

Impact on Other Systems and Technologies

In a high performance school, the HVAC system offers a range of cost saving opportunities. If accurate energy use estimates have been calculated (see Energy Analysis Tools *Building Block*), the HVAC system can be 'right sized' to meet these estimates. This approach invariably saves money over rule-of-thumb approaches which tend to oversize equipment. These savings can, in turn, be used to draw down the costs of other energy efficiency measures. Daylighting, for example, will not only reduce the need for electric lights, it will also reduce the heat these lights create. This reduction may be sufficient to allow for a smaller, less expensive air conditioning unit to be specified.

Resources

- American Society of Heating, Refigerating and Air Conditioning Engineers (ASHRAE) – www.ashrae.org
- Energy Star Program, U.S. Environmental Protection Agency – www.epa.gov/energystar
- Federal Energy Management Program – www.eren.doe.gov/femp/femp.html
- U.S. Department of Energy – www.eren.gov

Building Block #9 High Performance Electric Lighting

What

The quality of a school's electric lighting system has an enormous impact on the productivity of students, teachers, and staff, and on the facility's operating budget. A high performance school should provide superior electric lighting by optimizing 'watts per square foot' while retaining visual quality. This can be accomplished by specifying high efficiency lamps and ballasts, optimizing the number and type of luminaires (light fixtures) for each application, incorporating controls to ensure peak system performance, and integrating complementary electric lighting and daylighting design strategies.

Why

Electric lighting can account for 30 to 50 percent of a school's electric power consumption. Even modest efficiency improvements can mean substantial bottom line savings. This is especially true in locations subject to extra 'demand charges' during times of peak energy use. Since these charges usually occur during daytime hours when schools are in full operation, any efforts to reduce the demand for power during these times will reap additional savings. An added benefit: more efficient lighting produces less waste heat, thus reducing the need for cooling and further reducing operating costs. These savings are achievable now – in any school – using readily available equipment and controls.

How

Design for High Efficiency and Visual Comfort

- Develop individual lighting designs for individual rooms or room types (e.g., classrooms, hallways, cafeteria, library, etc.).
- Consider a mix of direct and indirect light sources for each design.
- Optimize each design so that overall lighting levels (watts per square foot) are as low as possible while still providing optimal illumination for the tasks at hand.
- Avoid overlighting any space.
- Analyze the impact of the lighting system on the HVAC system, and resize as appropriate.
- Design systems to facilitate cleaning and lamp replacement.

Ross Middle School
Ross, CA

This new, 200-student facility just north of San Francisco incorporates a full range of high performance electric lighting features. Direct/indirect pendant fixtures are used to provide high quality light at low foot-candle levels. In the daylit classrooms, these fixtures also include dimming ballasts and photosensors, so they are able to vary light output depending on the levels of available daylight. Used properly, this strategy alone can save up to 60% of the electrical energy needed for lighting these rooms.

Lights have two bulbs that are separately switched, so that half the lamps can be turned off at one time, further reducing energy consumption. Some lights are also tied to occupancy sensors, so that they automatically turn off when a room is unoccupied. Finally, the entire lighting system is on a timer to ensure that all lights are shut off at night.

These features, combined with daylighting in the classrooms, create a total system that delivers high quality lighting which is also energy and cost efficient. Architect Scott Shell hopes that these features "...will not only make the school a better place for teaching and learning, but will also be used as tools that help make children more aware of how buildings and their use of energy impact the environment."

How *(continued)*

Specify High Efficiency Lamps and Ballasts

- Use T-8 fluorescent lamps with electronic ballasts for most general lighting applications (classrooms, offices, multipurpose rooms, cafeterias).
- Consider using T-5 lamps if justified on a life cycle cost basis.
- Consider dimmable ballasts, especially in rooms that are daylit.

Optimize the Number and Type of Luminaires (lighting fixtures)

- Use suspended indirect or direct/indirect luminaires in classrooms to provide soft uniform illumination throughout the room.
- Consider incorporating additional accent and directional task lighting for specific uses (display areas, white boards, team areas, etc.)
- Consider the potential for using a smaller number of higher efficiency luminaires to light specific spaces, resulting in fewer fixtures to purchase, install, maintain, and clean.

Incorporate Controls to Ensure Peak System Performance

- Use occupancy sensors with manual overrides to control lighting (on-off) in classrooms, offices, rest rooms, storage areas, and other intermittently occupied spaces. Consider scheduled dimming and/or time clocks in other rooms.
- Consider incorporating lighting controls into the facility's overall energy management system, as appropriate.

Integrate Electric Lighting and Daylighting Strategies

- Treat the electric lighting system as a *supplement* to natural light; i.e., design for daylighting first and use the electric system to add light as needed during the day while providing sufficient illumination at night.
- Install controls that dim or turn lights off at times when daylight is sufficient.
- Consider photoelectric controls that are sensitive to levels of daylight.
- Consider controls that provide continuous, rather than stepped, dimming.

Impact on Other Systems and Technologies

Electric lighting systems interact strongly with a school's daylighting and HVAC systems. Daylighting strategies that are well-integrated with lighting equipment and controls will reduce the demand for electric light. If addressed by a combination of high efficiency electric lighting equipment and controls, this reduced demand can substantially lower a school's electricity usage. In addition, less electric lighting means less waste heat and, therefore, less demand for cooling. Cooling equipment can be downsized, resulting in first cost and operating cost savings to the school. *Note: Using suspended fixtures in classrooms will require ceiling heights of at least 9'6".*

Resources

- Designlights Consortium – www.designlights.org
- Energy Star Program – www.epa.gov/energystar
- Illuminating Engineering Society of North America – www.iesna.org
- Lawrence Berkeley National Laboratory – www.lbl.gov
- Lighting Research Center, Rensselaer Polytechnic Institute – www.lrc.rpi.edu
- Advanced Lighting Guidelines – www.newbuildings.org
- National Clearinghouse for Educational Facilities – www.edfacilities.org/ir/hottopics.cfm

Building Block #10 Life Cycle Cost Analysis

What

Life cycle cost analysis is a way assessing the total cost of facility ownership over time. Total life cycle costs consist of:

- Initial costs (design and construction);
- Operating costs (energy, water, other utilities, personnel)
- Maintenance, repair and replacement costs.

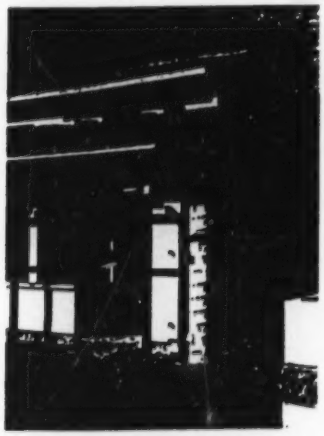
Life cycle analyses are used to predict these costs at various points during the design of a school. Predicted costs for alternative design approaches can then be compared until the approach that provides the lowest overall cost of ownership consistent with the quality level desired for the facility is selected.

Why

The true cost of a school is much more than the price to design and build it. The long-term costs of operating and maintaining the facility must also be included. Only by evaluating all three of these parameters can a community understand how much a new school really "costs."

And only by looking at all three parameters simultaneously can the impacts of alternative design approaches be evaluated. High performance classroom glazing, for example, may cost more upfront, but may result in energy savings that pay for the glazing upgrade in a few years and then continue to save money for years to come. Life cycle cost analysis is the key to making these kinds of comparisons and to creating new schools with the lowest long-term costs of ownership.

Special Note: One of the key impediments to optimizing school facilities from a life cycle perspective is the standard separation, common in school districts across the U.S., of capital and operating budgets. In such situations, there is little incentive to make capital spending decisions based on their potential for operational or maintenance savings. This approach often yields new schools that meet their budgetary constraints, but may be suboptimal from a total facility cost perspective. The only way to ensure that operation and maintenance costs become part of the capital cost decision-making process is to make life cycle cost analysis an integral part of the design process. The result will be schools that represent better long-term investments of a community's short-term capital funds.



Newport Coast Elementary School
Newport Coast, CA

A life cycle approach, which combines energy use projections with accurate construction cost estimates, was used to help guide the design of this K-6 school, just nearing completion in Southern California. The result is a highly integrated design – one that combines daylighting with high performance HVAC and electric lighting systems into an energy efficient whole. The school is projected to save its district substantial operating costs over time, yet because it was designed using a life cycle cost approach, it will cost no more to build than comparable schools in the area.

The school already won an award for its innovative and cost-effective approach to saving energy – the "2000 Saving Energy by Design Award for Energy Efficiency Integration." The jury appreciated the detailed performance analyses and investigative studies that were conducted over the course of the design process. One jury member commented that "The energy investigation should be a textbook for school design."

How

A variety of life cycle cost analysis tools are currently available, some appropriate for the early stages of a project when rough cost estimates are all that is required, others developed for use in the later phases, when detailed product and material 'take offs' are possible. One or a combination of these tools should be used to assess design alternatives at least once during each of the following design phases:

- Programming
- Schematic Design
- Design Development
- Construction Documents
- Bidding and Negotiation

Impact on Other Systems and Technologies

Life cycle cost analysis impacts virtually every system in a school. Used properly, such analyses can optimize the integrated performance of all these systems and thereby reduce a school's total cost to the community.

Resources

Life Cycle Cost Analysis Tools

- U.S. Department of Energy – www.eren.gov/buildings/tools_directory
- Geoexchange – www.geoexchange.org/dsgntool/lccdes.htm
- Whole Building Design Guide – www.wbdg.org

Construction Costs

- U.S. Cost – www.uscost.com
- R.S. Means – www.rsmeans.com

Maintenance Costs

- Whitestone Research – www.whitestoneresearch.com
- Building Owners and Managers Association – www.boma.org

Building Block #11 Renewable Energy

What

Renewable energy – particularly solar and wind energy – is a free resource which, if effectively captured and used, can significantly reduce a school's operating costs. A high performance school should maximize the cost-effective use of renewable systems to meet its energy needs. The school district should also consider purchasing 'green power.'

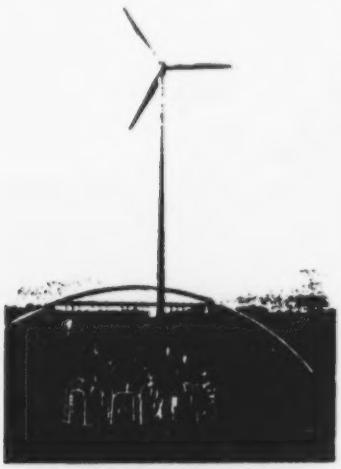
Why

Renewable energy systems reduce a school's overall operating expenses and play a significant role in preserving the environment. Many of the techniques employed (for example, daylighting and natural ventilation) also contribute to a high quality learning environment. Other strategies, particularly solar thermal, wind, and photovoltaic applications, are exciting technologies that can be used to teach students about science, ecology, and the environment.

How

During the design process, the developers of a high performance school should systematically evaluate and consider integrating one or more of the following renewable energy systems into the building:

- Daylighting – maximize the amount of natural light throughout the school (see High Performance Schools Building Block #3 – Daylighting).
- Passive Solar Heating – to meet some of the school's heating needs, capture the sun's energy through southfacing windows.
- Solar Hot Water – capture the sun's energy in ground- or roof-mounted systems that provide some or all of a school's hot water needs.
- Solar Thermal – capture the sun's energy in ground- or roof-mounted systems to help heat the school or, using an absorption system, to help cool it.
- Geothermal Heat Pump – transfer heat to and from the earth to generate energy efficient heating and cooling.
- Natural Ventilation – design to facilitate the circulation of 'nonconditioned' outside air through the building and to take advantage of prevailing breezes.
- Wind – use wind energy to generate on-site electricity.
- Photovoltaics – use ground-mounted, roof-mounted, or building-integrated systems to transform sunlight into electricity.
- Green Power – purchase power from producers who generate electricity from renewable sources.



Spirit Lake Elementary School
Spirit Lake, IA

This elementary school near the Iowa/Minnesota border installed a single wind turbine on the school grounds in July, 1993. Since then, the turbine has produced enough clean, non-polluting electricity to meet virtually all of the school's needs. In the first seven years of the turbine's operation, the school paid only $568 to its utility for electric power.

"The final payment for the loan on the first turbine was made in the 1998 fiscal year. Today, $25,000 per year in savings go to the school's instructional programs," notes Jim Tirevold, Facilities Manager for Spirit Lake Community Schools. On top of that, the turbine is considered an excellent tool for teaching children about science and the environment.

The installation has been so successful that the district is considering installing a second, larger turbine to provide other schools in the area with similar benefits.

Impact on Other Systems and Technologies

Renewable energy systems closely interact with the heating/ventilating/air conditioning (HVAC), hot water and electric power systems in a building. Passive solar and solar thermal systems provide heat, which reduces demand on the HVAC system. Daylighting reduces the need for electric lighting, while natural ventilation reduces the need for mechanical venting. Solar hot water replaces mechanically heated water, and geothermal heat pumps replace conventional heating/air conditioning equipment. Wind and photovoltaics provide electricity, thus reducing the need for utility-provided power.

Resources

- American Bioenergy Association – www.biomass.org
- American Solar Energy Society – www.ases.org
- American Wind Energy Association – www.awea.org
- Center for Resource Solutions – www.resource-solutions.org
- Geothermal Heat Pump Consortium – www.ghpc.org
- Green Power Network – www.eren.doe.gov/greenpower
- Green-E Renewable Electricity Program – www.green-e.org
- Renewable Energy Alliance – www.realliance.org
- Solar Energy Industries Association – www.seia.org
- Solar Rating Certification Corporation – www.irecusa.org/solRatCC.html
- Sustainable Buildings Industry Council – www.sbicouncil.org
- U.S. Department of Energy – www.eren.gov
- Utility Photovoltaic Group – www.upvg.org

Building Block #12 Safety & Security

What

Safety and security have become critical concerns for students, teachers, and parents across the country. A high performance school should create a safe and secure environment by *design*. Opportunities for natural surveillance should be optimized, a sense of territoriality should be reinforced; access should be controlled, and technology should be used to complement and enhance, rather than substitute for, a facility's security-focused design features.

Boscawen Elementary School
Boscawen, NH

'Room like,' non-institutional corridors, plenty of views out and in, and windows between the classrooms and the hallway all combine to improve the safety and sense of security in this southern New Hampshire school.

Why

Crime and vandalism – and the fear they foster – are problems facing school populations throughout the United States. While better buildings cannot solve these problems alone, they can be powerful factors in helping reduce crime and other antisocial behavior. Thoughtful design that builds on basic Crime Prevention through Environmental Design (CPTED) principles is the key.

How

Increase Opportunities for Natural Surveillance

- Design landscaping to minimize places that are hidden from view.
- Ensure that key areas – parking, bicycle storage, drop-off points, play equipment, entries – are easily observable from inside the building.
- Design exterior lighting to facilitate nighttime surveillance.
- Consider providing views (using glazed doors or windows) from classrooms into circulation corridors.
- Design to minimize areas within the building that are hidden from view.
- Consider open stairwells.

Reinforce a Sense of Territoriality

- Foster a sense of 'ownership' of the school by students and teachers.
- Clearly define borders – what is part of the school and what is not.
- Consider decorative fencing and special paving treatments to delineate the boundaries of the school grounds.
- Consider designing common areas – particularly corridors – that are less institutional and more 'room like.'
- Consider materials and finishes that are graffiti resistant.

How *(continued)*

Control Access to the Building and the Grounds

- Consider decorative fencing to control access to school grounds.
- Limit the number of entries to the building.
- Allow visual surveillance of all entries from inside the school.
- Provide the ability to 'lock down' parts of the school when the facility is used for after-hours activities.

Integrate Security Technology

- Consider incorporating interior and exterior surveillance cameras.
- Ensure that all high-risk areas (office, cafeteria, shops, labs, etc.) are protected by high security locks.
- Consider metal detectors and other security technologies, as appropriate.

Impact on Other Systems and Technologies

Security-based *design* strategies will influence a school's basic layout and site plan. If properly integrated from the outset of the development process, these influences will complement and enhance other high performance design strategies used in the facility. For example, daylit classrooms can 'share' their natural light with adjacent corridors through windows or glass doors provided primarily for surveillance purposes. This natural light can, in turn, be used to offset the need for artificial lighting in the corridors.

Security *technology* strategies will not strongly impact other systems in the school, unless they are incorporated into a comprehensive automated control system for the entire facility.

Resources

- *Crime Prevention through Environmental Design*, Timothy D. Crowe, Boston: Butterworth-Heinman, January 2000
- *Defensible Space*, Oscar Newman, New York: Macmillan, 1972
- *Designing Safer Communities: A Crime Prevention through Environmental Design Handbook*, National Crime Prevention Council, 1997 – www.ncpc.org
- American Society of Industrial Security – www.asisonline.org
- National Resource Center for Safe Schools – www.safetyzone.org
- Keep Schools Safe – www.keepschoolssafe.org
- National Clearinghouse for Educational Facilities – www.edfacilities.org/ir/hottopics.cfm

Building Block #13 Superior Indoor Air Quality

What

The quality of the air inside a school is critical to the health and performance of children, teachers, and staff. A high performance school should provide superior quality indoor air by controlling the sources of contamination, providing adequate ventilation, preventing unwanted moisture accumulation, and implementing effective operations and maintenance procedures.

Why

According to the U.S. Environmental Protection Agency, the concentration of pollutants inside a building may be two to five times higher than outside levels. Children are particularly vulnerable to such pollutants because their breathing and metabolic rates are high relative to their size – much higher than for adults. Maintaining a high level of indoor air quality is therefore a critical issue for schools to address. According to the EPA, failure to do so may...

- Negatively impact student and teacher performance;
- Increase the potential for long- and short-term health problems for students and staff;
- Increase absenteeism;
- Accelerate deterioration and reduce efficiency of the school's physical plant;
- Create negative publicity that could damage a school's image;
- Create potential liability problems.

'Designing in' superior indoor air quality from the beginning is the most cost-effective way to avoid these negative outcomes and ensure a healthy and productive indoor environment.

How

Design

- Consult *Indoor Air Quality for New Schools* from the U.S. Environmental Protection Agency (www.epa.gov/iaq)

Control Sources of Contamination

- Test the site for sources of contamination: radon, hazardous waste, fumes from nearby industrial or agricultural uses.
- Locate sources of exhaust fumes (e.g. from buses, cars, or trucks) away from air intake vents.
- Consider recessed grates, 'walk off' mats, and other techniques to reduce the amount of dirt entering the building.

Boscawen Elementary School
Boscawen, NH

This 53,000 square foot, 420-student school north of Concord, New Hampshire is the first in the country to use a combined displacement and demand-control ventilation system to provide superior indoor air quality and thermal comfort with reduced overall energy costs.

Fresh outside air is brought into the building, filtered, and passed through heat exchangers which warm it. The air is then pumped at low velocity to the classrooms where it is delivered through diffusers near the floor. The fresh, warm air slowly rises through the rooms until it is finally removed through ceiling vents. The air then passes back through the heat exchangers before it is exhausted to the outside. The heat it 'gives back' to the exchangers is used to warm incoming fresh air. None of the air is recirculated, and the result is a school with exemplary indoor air quality which is, at the same time, energy and cost efficient.

As Dr. G.W. Porter of the New Hampshire State Department of Education notes, "Despite the innovative engineering, its cost was equal [to], or possibly less than, other typical schools. Maintenance costs, such as heating, are expected to be lower, and even without air conditioning, the building will be even cooler in spring and fall. Air quality, a problem that's plagued a number of our schools, will also be vastly improved."

How *(continued)*

- Specify materials and furnishings that are low emitters of indoor air contaminants. Consider:
  - Adhesives and sealants with low levels of volatile organic compounds (VOCs);
  - Paints and coatings that meet or exceed the VOC and chemical component limits of the Green Seal requirements;
  - Carpet systems that meet or exceed the Carpet and Rug Institute's Green Label Indoor Air Quality Test Program;
  - Composite wood or agrifiber products containing no added urea-formaldehyde resins.
- Allow adequate time for all installed materials and furnishings to 'outgas' before the school is occupied. Assist the process by running the HVAC system continuously at the highest possible outdoor air supply setting for at least 72 hours after all materials and furnishings have been installed in order to 'flush out' the facility.

Provide Adequate Ventilation

- Design the ventilation system to provide a minimum of 15 cubic feet per minute per person of filtered outdoor air to all occupied spaces (consider 20 cubic feet per minute).
- Ensure that ventilation air is effectively delivered to and distributed through the school rooms.
- Provide local exhaust for restrooms, kitchens, science labs, janitor's closets, copy rooms, and vocational/industrial shop rooms.

Prevent Unwanted Moisture Accumulation

- Avoid ventilation air that is too moist; design the ventilation system to maintain the indoor relative humidity between 30% and 50%.
- Design to minimize water vapor condensation, especially on walls and the underside of roof decks, and around pipes or ducts.
- Design to keep precipitation out of the building: off the roof and away from the walls.

Operate and Maintain the Building Effectively

- Regularly inspect and maintain the ventilation system so that it continues to operate as designed.
- Install CO_2 sensors in large assembly areas (auditorium, gym) to provide real-time monitoring of air quality.
- Design cleaning and maintenance programs to minimize the use of toxic materials.
- Use *Indoor Air Quality – Tools for Schools* by the U.S. Environmental Protection Agency, to guide the O&M process.

Impact on Other Systems and Technologies

Increasing ventilation to improve indoor air quality will have an impact on the size and operation of the overall HVAC system. The entire systems should be "right sized" and make use of appropriate technology to provide the optimum level of ventilation air in the most energy and cost effective manner possible.

Resources

- *ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality* and *ASHRAE 129-1997*, Association of Heating, Refrigerating and Air Conditioning Engineers – www.ashrae.org
- *ASTM D 6245-1998: Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation*, American Society for Testing and Materials – www.astm.org
- Carpet and Rug Institute – www.carpet-rug.com
- Green Seal – www.greenseal.org
- *Indoor Air Quality Tools for Schools* and *Indoor Air Quality Tools for NEW Schools*, U.S. Environmental Protection Agency – www.epa.gov/iaq
- *School Indoor Air Quality Best Management Practices*, Washington State Department of Health – www.doh.wa.gov/ehp/ts/IAQ
- *National Clearinghouse for Educational Facilities – www.edfacilities.org/ir/hottopics.cfm*

Building Block #14 Thermal Comfort

What

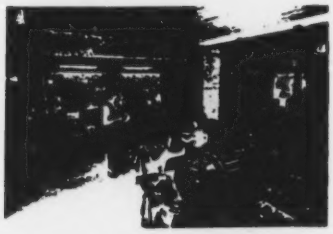
Thermal comfort is a function of the temperature and relative humidity in a room. While the building code requires minimum levels of temperature and humidity in occupied spaces, it does not specify how these levels are to be achieved, leaving open the possibility that individual areas within a room may be too hot or too cold. Further, code levels are only minimums – the optimal levels for specific applications may be quite different. A high performance school should ensure that rooms and HVAC systems are designed to allow temperature and humidity levels to remain within the 'comfort zone' at all points in an occupied space.

Why

Thermal comfort is an important variable in student and teacher performance. Hot, stuffy rooms – and cold, drafty ones – reduce attention spans and limit productivity. They also waste energy, adding unnecessary cost to a school's bottom line. Excessively high humidity levels can also contribute to mold and mildew.

How

- Comply with American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 55-1992 (with 1995 Addenda) *Thermal Environmental Conditions for Human Occupancy*.
- When a design incorporates natural ventilation (e.g., opening windows to provide direct outdoor air during temperate times of the year), consider adjusting the requirements of ASHRAE Standard 55-1992 to account for the impact.
- Analyze room configurations and HVAC distribution layouts to ensure that all parts of a room are receiving adequate ventilation.
- Analyze placement of windows and skylights and provide adequate, controllable shading to avoid 'hot spots' caused by direct sunlight.
- Consider providing a temperature and humidity monitoring system to ensure optimal thermal comfort performance.
- Evaluate the inclusion of temperature and humidity monitoring as part of the building's overall energy management system.
- Consider providing controls in each room to offer teachers more direct control over thermal comfort.
- Evaluate the potential impact of such controls on the overall efficiency of the HVAC system.



The Advantage Classroom™

The Advantage Classroom™ is a design concept developed by The H. L. Turner Group in Concord, NH. Among other attributes, the Advantage Classroom provides superior thermal comfort through a design approach that combines low velocity ventilation, room air stratification, and dehumidification cooling. This approach, which has been applied at more than 20 schools in New England, reduces drafts and 'hot spots,' enhances efficiency and control by including thermostats in each room, reduces room noise, and ensures optimal temperature and humidity levels through ongoing monitoring of room conditions.

Kim Cheney, a teacher at one school built with Advantage Classrooms, is very satisfied with the results: "Everything about it is incredible; the white boards eliminate chalk dust, the air is clean, the temperature is perfect, it's all so comfortable. In the old school ...we'd be really cold, but if you turned on the heat it would get so hot the students would get tired in the afternoon. In moving into the new school, we went from the 19th Century straight to the 21st."

Impact on Other Systems and Technologies

Thermal comfort is strongly influenced by how a specific room is designed (How much heat does its walls and roof gain or lose? How much sunlight do its windows let in? Can the windows be opened? etc.) and by how effectively the HVAC system meets the specific needs of that room. Balancing these two components – room design and HVAC system design – is a back-and-forth process that continues throughout all stages of new facility development.

In a high performance school, the process results in an optimal blend of both components: rooms configured for high student and teacher productivity served by an energy efficient HVAC system. The system is designed, sized, and controlled to maintain thermal comfort under all conditions.

Resources

- American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) – www.ashrae.org

Building Block #15 — Visual Comfort

What

For both students and teachers, performing visual tasks is a central component of the learning process. A high performance school should provide a rich visual environment – one that enhances, rather than hinders, learning and teaching. These environments are achieved by carefully integrating natural and artificial lighting strategies, by balancing the quantity and quality of light in each room, and by controlling or eliminating glare.

Why

Students spend much of their day engaged in visual tasks – writing, reading printed material, reading from visual display terminals, or reading from blackboards, whiteboards, and overheads. Further, they must constantly adjust their vision from 'heads up' to 'heads down' positions and back again. Inadequate lighting and/or glare in these situations can seriously impact a student's ability to learn. On the other hand, a comfortable, productive visual environment – one that takes into account more than simply the amount of light hitting the desk top – will enhance the learning experience for both students and teachers.

How

Integrate Natural and Artificial Lighting Strategies

- Take the amount of daylight entering a room into account when designing and sizing the artificial lighting system for that room.
- Provide controls that turn off lights when sufficient daylight exists.
  - Consider dimming controls that continuously adjust lighting levels to respond to daylight conditions.

Balance the Quantity and Quality of Light in Each Room

- Avoid excessively high horizontal light levels.
  - Use the newly revised 9th edition of the Illuminating Engineering Society of North America's *Lighting Handbook: Design and Application* as a guide.
- Design for 'uniformity with flexibility.'
  - Illuminate spaces as uniformly as possible, avoiding shadows or sharp distinctions between dark and light.
  - As appropriate, provide task or accent lighting to meet specific needs (e.g., display areas, white boards, team areas, etc.).
- Develop individual lighting strategies for individual rooms or room types (e.g., classrooms, hallways, cafeteria, library, etc.). Avoid 'one size fits all' approaches.

Durant Road Middle School
Wake County, NC

Daylighting and electric lighting are seamlessly integrated in this 1300-student school in Raleigh, North Carolina. The design team repeatedly analyzed the interactions between the size and location of the roof monitors; the size and configuration of the electric lighting fixtures; the color and reflectance of the walls, floor and ceiling; and the amount of light hitting the desks.

"We worked the problem using computer simulation tools until we had just the right combination. The result is a group of classrooms that are bright, fun places to be, that rely on natural sunlight for the bulk of their lighting needs, that virtually eliminate glare, and that save the school money on energy, all at the same time," notes Mike Nicklas, chief architect for the project.

Because of the Durant School's exceptional daylit design, it was featured on CNN's "Science and Technology Week" series.

How *(continued)*

Control or Eliminate Glare

- Consider how light sources in a room will impact work surfaces. Design to avoid:
  - Direct glare from sources in front or to the side of a work area;
  - Overhead glare from sources above the work area; and
  - Reflected glare from highly reflective surfaces, including glossy paper and computer terminals.
- As methods of control, consider increasing the brightness of surrounding surfaces, decreasing the brightness of light sources, or both.
- Consider interior (shades, louvers, blinds) or exterior (overhangs, trees) strategies for filtering daylight and controlling glare from sunlight.

Impact on Other Systems and Technologies

Visual comfort results from a well-designed, well-integrated combination of natural and artificial lighting systems. Any strategy for enhancing the visual environment will therefore strongly impact the size and configuration of both of these systems (e.g., number, type, and placement of windows; number, type, and placement of light fixtures; etc.). The final configurations will, in turn, impact a school's heating and cooling systems.

An optimized overall design will provide a high quality luminous environment and will use daylight effectively to reduce the need for artificial lighting. Less artificial lighting means lower electricity bills and less waste heat which, in turn, reduces the demand for cooling and lowers overall HVAC operating expenses.

Resources

- Advanced Lighting Guidelines – www.newbuildings.org
- Designlights Consortium – www.designlights.org
- Energy Star Program – www.epa.gov/energystar
- Illuminating Engineering Society of North America – www.iesna.org
- Lighting Research Center, Rensselaer Polytechnic Institute – www.lrc.rpi.edu
- Lawrence Berkeley National Laboratory – www.lbl.gov

What

In many parts of the country, fresh water is an increasingly scarce resource. A high performance school should reduce and control water runoff from its site, consume fresh water as efficiently as possible, and recover and reuse graywater to the extent feasible.

Why

Basic efficiency measures can reduce a school's water usage by 30% or more. These reductions help the environment, locally and regionally. They also lower a school's operating expenses. While the cost savings may be modest now, since water is relatively inexpensive in most areas of the country, there is a strong potential that the value of these savings will rise over time, especially in areas of the country where water is scarce and becoming more expensive.

The technologies and techniques used to conserve water – especially landscaping, water treatment and recycling strategies – can be used to help instruct students about ecology and the environment.

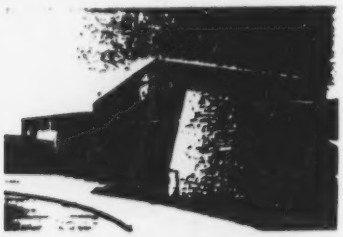
How

Water-Efficient Landscaping

- Specify hardy, native vegetation.
- Consider using an irrigation system for athletic fields only, not for plantings near buildings or in parking lots.
- Use high efficiency irrigation technology (e.g., drip irrigation in lieu of sprinklers).
- Use captured rain or recycled site water for irrigation. "Design in" cisterns for capturing rain water.

Water Use Reduction

- Set water use goals for the school. Recommendation: 20% less than the baseline calculated for the building (not including irrigation) after meeting the Energy Policy Act of 1992 fixture performance requirements.
- Specify water conserving plumbing fixtures that exceed Energy Policy Act of 1992 requirements.
- Specify high efficiency equipment (dishwashers, laundry, cooling towers).
- Consider single temperature fittings for student toilets/locker rooms.
- Consider automatic lavatory faucet shut-off controls.
- Consider low-flow showerheads with pause control.
- Consider using recycled or rain water for HVAC/process make up water.



Roy Lee Walker Elementary School McKinney, Texas Independent School District

Rain is "harvested" from the roof of this 608-student, K-5 school 30 miles north of Dallas, Texas and used to water the grounds and flush the toilets year round. The water is stored in six above-ground cisterns designed as integral components of the overall architecture of the facility.

The system shows how incredibly efficient rainwater collection can be, even in relatively dry locations. According to architect Gary Keep, just using the roof, "...enough water can be collected in a one-year period to flush toilets and water the grounds for about six years."

How *(continued)*

Innovative Wastewater Treatment

- Decrease use of potable water for sewage conveyance by using gray and or black water systems. Opportunities include toilet flushing, landscape irrigation, etc.
- Consider on-site wastewater treatment, including full or partial "solar aquatics" systems.

Impact on Other Systems and Technologies

Using less hot water will reduce energy costs. This reduction should be factored in to all life cycle cost analyses performed for the facility.

Resources

- EPA Office of Water, U. S. Environmental Protection Agency – www.epa.gov/OW
- *Guiding Principles of Sustainable Design (Chapter 8)*, National Park Service – www.nps.gov/dsc/dsgncnstr/gpsd
- National Clearinghouse for Educational Facilities – www.edfacilities.org/ir/hottopics.cfm
- Water Alliance for Voluntary Efficiency (WAVE) – http://es.epa.gov/partners/wave/wave.html
- WaterWiser: The Water Efficiency Clearinghouse – www.waterwiser.org

Case Study: Boscawen Elementary School Boscawen, New Hampshire

Innovation and Teamwork Create a High Quality Learning Environment in Southern New Hampshire.

Everyone knew it was time for a change at Boscawen Elementary. The teachers knew it. The students knew it. The parents and administrators knew it.

The existing school – an 1860s structure that had last been upgraded 30 years before – was so crowded that some classes were being taught in the hallways. More disturbing, the air quality inside the building was so bad that people were getting sick. In 1995, the school was once evacuated after students complained of foul odors. Everyone agreed that a new school – one with excellent indoor air quality – was a top priority, and voters overwhelmingly supported the funding referendum.

Unfortunately, the amount of available funding was very limited: just $65 per square foot for construction. This was at the low end of the $60 - $80/s.f. range prevalent in New Hampshire at the time, and it placed significant restraints on the team responsible for carrying out the project. Fortunately, the team – owner, architect, and construction manager – had a strong commitment to quality and to working cooperatively with one another in pursuit of shared goals. Equally important, they weren't afraid to innovate in order to achieve the high levels of performance they were striving for.

This was especially true in their approach to designing the classrooms, where they paid special attention to acoustics, lighting quality, and ventilation. They integrated all three into a seamless design that the architects dubbed the Advantage Classroom. It features a unique room configuration – wing walls, valences, a peaked ceiling, and angled corners – that contributes to good acoustics by breaking up and absorbing sound while allowing light to spread evenly throughout the space. The shape of the room also helps the unique 'displacement ventilation' system to function at peak efficiency.

By focusing on the classroom, the team was very consciously lavishing the most attention – and the bulk of their resources – on the spaces where students and teachers spend the majority of their time. Other areas were not ignored, but as the school's primary learning environments, the classrooms were regarded as exerting the greatest possible influence on student and teacher performance.

The results bear out the wisdom of this approach. The school is *healthy and productive*, with great air quality, acoustical performance, and visual comfort ...especially in the classrooms. It is *cost effective* in that, even on a very tight budget, the development team was able to reduce operating costs by 'designing in' energy efficiency in the building shell, in the lighting, and in the heating/ventilating/air conditioning system. And finally, the school is *sustainable*, in that it's designed using environmentally responsible and energy conserving materials and systems.

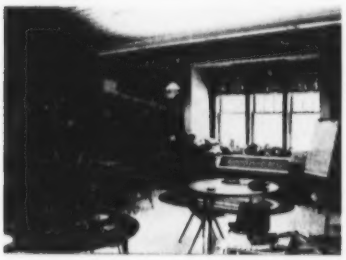
Jane Lacasse, principal during Boscawen's construction, describes the school as "...an environment that's going to enhance our educational efforts. We expect to take off and do some remarkable things."

Key Features:

- *Spatially unique classrooms;*
- *Superior acoustics;*
- *High quality electric lights;*
- *An innovative 'displacement ventilation' system that provides 100% fresh air to the school.*

"The Advantage Classroom concept that has been created at the Boscawen Elementary School is the best I've seen in my 40 years in public education, and I commend it to school leaders throughout the nation."
– Dr. Richard Goodman
Executive Director, New Hampshire School Administrators Association Champions for Children

Boscawen Elementary Q&A



"The project had many new dynamics related to the materials and systems used, from the foundation and the use of metal studs, right down to the control system. The whole effort was really a team approach, where all the construction team members had input on the practicality versus the cost. It is a remarkably inexpensive school when one considers the amount of effort and technology that went into it. It's staggering to see what was accomplished with what would be considered an average school construction budget. We're very proud of the building."

– Steve Horton
Project Manager,
The MacMillin Company

Did Boscawen Elementary cost more to build?

No. The cost to construct the school (exclusive of site costs) was $65 per square foot in 1996 dollars. This amount was on the low side for New Hampshire, where costs at that time ranged from $60 to $80 per square foot. Since there was no question of obtaining extra funds to procure a 'high performance' school, the features that make the school a superior environment for learning had to be provided within conventional – and very tight – budgetary constraints.

How was a high performance school delivered on such a tight budget?

The keys to getting high performance from a low budget were cooperation and prioritization: cooperation among the three key players in the development process (owner, architect, and construction manager) and prioritization of the components of the facility, so that performance was favored over other potential concerns.

Harold Turner, head of design firm H.L.Turner Group, describes the process as follows: "We knew going in that financial resources would be tight. So we made a very conscious decision to value educational performance over aesthetic performance when we had to make the hard choices. However much we might have wanted a knockout atrium as a gathering space or a really elegant covered entrance promenade, we would – and did – sacrifice such elements [so as] to put more resources into the classrooms where the kids and teachers spend most of their time. The result is a modest but attractive-looking school that doesn't reveal its greatest asset – high performance teaching and learning environments – until you're actually inside the classrooms."

Such tradeoffs would not have been possible without close cooperation between the owner (in this case, the school board, the principal, the superintendent's office, and the building committee), the architect, and the construction manager. At Boscawen, all the major players were committed to doing whatever was necessary to deliver the highest quality learning environment possible. As Turner notes, "Without close cooperation, we never could have made the trade-offs that we did to bring the school in on time and on budget. When everybody has the same basic agenda – achieving quality and high performance – it's much easier to make the hard decisions needed to get the job done."

SUSTAINABLE BUILDINGS INDUSTRY COUNCIL

SBIC is a nonprofit organization whose mission is to advance the design, affordability, energy performance, and environmental soundness of residential, institutional, and commercial buildings nationwide. As the foremost national resource for sustainable design and product information, SBIC offers professional training, consumer education, and energy analysis tools. SBIC publishes accurate, easy-to-use guidelines, software, and general information about energy conservation measures, energy efficient equipment and appliances, daylighting, and sustainable architecture. To learn more, visit SBIC at www.SBICouncil.org or call 202-628-7400.

Boscawen Elementary Q&A

To achieve high performance and stay within budget, where did the development team spend and where did it save?

The primary areas of extra expenditure were:

- Special configurations in the classrooms (peaked ceilings, valences, and angled corners);
- Construction detailing that provided a continuous air infiltration barrier around the entire structure;
- Specialized lighting design in the classrooms; and
- A unique ventilation system that utilizes high-end air handling units not usually found in schools.

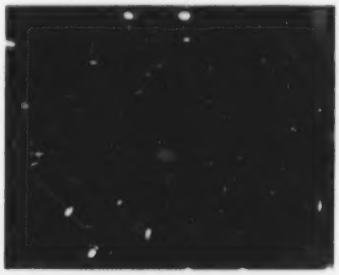
In addition, an oversized gym was included to serve, in conjunction with the café area, as a much-needed and much-used community meeting space for the town of Boscawen. These extra features added roughly 3 – 5 percent to the construction budget.

Savings were achieved in ways both large and small. For example, a major decision was made early on to utilize a unique steel framing system for the entire building shell, rather than a more traditional system of wood frame walls combined with wood or steel trusses for the roof. Because wood prices were high at the time, the decision resulted in substantial savings that were used to offset extra expenditures in the classrooms.

Similar savings were achieved in the interior corridors, where steel studs and gypsum board were used for the walls, rather than the more durable, but slightly more expensive, masonry. To deal with 'hands on' dirt and damage from small children, a wainscotting of ceramic tile was installed up to a height of 36 inches. This approach put the durability where it was most needed, and *only* where it was needed, thus keeping first costs down. *(Note: this strategy works well in an elementary school, but would need to be changed for a middle or high school, where students are taller and stronger, and very durable walls are a necessity.)*

What was the owner's role in making Boscawen Elementary a high performance school?

The 'owners' at Boscawen Elementary – the school board, principal, superintendent's office, and the building committee – were critical to the ultimate success of the facility. Everyone was committed to trying something new in order to obtain a high quality school; in particular, one with superior indoor air quality. "That is something the school board wanted to address from the very start," noted Bernard Davis, business superintendent for the Merrimack Valley School District where Boscawen is located. "The old building had terrible air quality."



The oversized gym is a real community asset, since schools really come alive here after 3 o'clock. There are school activities, community activities, and classes. This building will get a lot of use during the school year, on evenings and weekends, and during the summer. We designed the whole school – especially the gym and neighboring cafeteria – with this type of extended use in mind and it works great!

– Loren Belida, AIA
The H.L. Turner Group

Boscawen Elementary Q&A

People are rightly proud that we've not only come up with something new, but also a concept that leads. Ultimately, the children benefit, which is what it's all about. Their learning activities will improve because the learning environment is an important element toward that end.

– *Bernie Davis*
Assistant Superintendent for Business, Merrimack Valley School District

Because of the concern over air quality, the owners were receptive to a new ventilation strategy that provides 100% fresh air to the building. The technique, in which indoor air is not recirculated, is common in Europe but not widely used in the U.S. The Turner Group combined this technique with innovative approaches to lighting and acoustic control to create the Advantage Classroom prototype. With public and private support, they even constructed a 3/4-scale prototype of the classroom to demonstrate and test their design ideas. The Boscawen Board visited the prototype, and was sufficiently impressed to take a chance on using the designs in their new school. This commitment to innovation proved critical to the success of the entire project. Without it, the tough decisions over trade-offs and cost reduction measures would have been difficult if not impossible to make. With buy-in from the owners, the process moved smoothly forward, resulting in a facility that all participants are proud of.

Did Boscawen Elementary take longer to build than comparable schools in New Hampshire?
No. Construction was no more complicated or time consuming than for any comparable elementary school in the region.

Was an integrated, 'whole building' approach used for the design of Boscawen Elementary?
Yes. Without such an approach, the successes achieved at Boscawen would not have been possible. The design involved an ongoing process of analyzing and modifying alternative approaches until the optimal balance between performance and available funds was achieved. A key underlying objective was to have every component of the building be as high performing as it needed to be and no more. The only way to achieve this objective was to view each component in terms of how it fit in and interacted with all the other components of the 'whole building.'

The design team for Boscawen Elementary was especially lucky to have construction management firm The MacMillin Company on board early on in the process. This allowed accurate cost estimates to be generated as different alternatives were being analyzed. The result was that key decisions, particularly those concerning trade-offs, were made quickly and decisively. This 'rapid response' approach helped keep the whole effort on track and on budget.

Did Boscawen Elementary cost more to design?
No and yes. The design did not cost the owner any more than a normal school. However, because this was the first school of its type, it cost the design team a good deal more than they were able to be compensated for. They knew this going in and viewed the entire process as an investment in the future of their firm. As Bill Johnson of the Turner Group recalls, "We put many more hours into this project than we actually got paid for, but it was worth every minute because of the experience we gained. We're putting that experience to work now on every school we design – over 20 since we completed Boscawen – and we're reaping the benefits. We're producing high quality schools all across the region, we're

bringing them in on time and on budget, and we're staying profitable in the process."

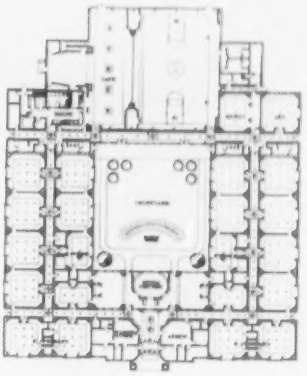
Is Boscawen Elementary harder to operate and maintain than a comparable school?
No, but... in general, the controls and equipment at Boscawen Elementary are no more complicated than systems found in equivalent schools throughout the region. However, because the ventilation system and its controls are different than most, operating personnel need some training in their correct operation and maintenance. Such training is not complicated, but it's necessary to ensure proper O&M.

Unfortunately, the controls contractor at Boscawen Elementary did not install the system correctly or provide adequate training (the contractor went out of business soon after the project was completed). This caused some initial problems at the school until the design team took it upon themselves to fine-tune the system and train personnel in its operation. It now functions properly, but if new operations personnel are hired, they too must be trained on the system. A robust commissioning process would have addressed the training issue before it became a problem. As a consequence, the architects now make commissioning an integral part of every new school they design.

With respect to maintenance, the school's materials, finishes, and equipment are easy to maintain using standard products and processes. The design also incorporates utility catwalks over the corridors to allow maintenance personnel access to all mechanical and electrical systems without needing to disrupt classes by removing classroom ceilings. Architect Loren Belida observed that "It's great for the maintenance people. They can access everything directly from the catwalks."

What barriers did the development team need to overcome to create Boscawen Elementary?
Once the decision to go forward with an innovative design had been made, there were few external barriers to creating Boscawen Elementary. At the state level, New Hampshire is not particularly intrusive with respect to local decisions, so no major regulatory or procedural roadblocks were encountered. In addition, there was no adversarial activity in the local community.

The only real barrier was internal, and involved the difficulty of creating a high performance facility within a very constrained budget. The key to overcoming this barrier was cooperation between the key players for the project – the design team, the construction manager, and the owners. "When you've got the kind of teamwork and cooperation we had, the sky's the limit," notes Turner Group architect Loren Belida. "Without it, the barriers are really difficult to overcome. Every decision is a struggle, and in the end, the quality of the building suffers."



The issue today is how do you do more with the same budget that everybody else has been working with. At Boscawen, we've shown that you can get a better operating environment in a school and do it for the same amount of money you'd spend not to have one. It involves a total reengineering of the building, but with the right amount of planning – and the right team – it can be done. We've proved it at Boscawen."

– Harold Turner
President,
The H.L. Turner Group

The Building Blocks of Boscawen Elementary

"Everything about it is incredible; the white boards eliminate chalk dust, the air is clean, the temperature is perfect, it's all so comfortable. In the old school ...we'd be really cold, but if you turned on the heat it would get so hot the students would get tired in the afternoon. In moving into the new school, we went from the 19th Century straight to the 21st."

– Kim Cheney
Teacher, Boscawen Elementary

Acoustic Comfort
Classrooms are intentionally configured to enhance acoustical performance: wing walls at the entrances, valences around the perimeter, and angled corners, all help to break up sound. In addition, the large open areas under the peaked ceilings in the classrooms and common-use spaces help dampen noise reverberation. Acoustical decking on the underside of the ceilings provides additional sound absorption, so that teachers' voices carry clearly to all parts of the classroom. Boscawen's unique, low-velocity ventilation system is also very quiet, thus reducing unwanted background noise.

Commissioning
The architect/engineer team provided limited commissioning services on the project, focusing on the heating/ventilating/air conditioning (HVAC) system. Because of budgetary and time constraints, a commissioning agent was not used. Based on the positive results of the process, the architects have significantly expanded their use of commissioning on new projects, and now provide in-depth services, including a commissioning agent, on all the schools they design.

Daylighting
Windows are optimally sized and configured to work with the electric lighting in each room. The amount of daylight is balanced with the levels of luminescence provided by the lighting system to ensure optimal light levels throughout the day. The shading coefficients for the windows also vary, depending on which direction they face (this strategy helps reduce overheating). Operable windows provide natural ventilation, although the teachers typically keep them closed because the ventilation system already provides 100% fresh air to each room.

Energy Analysis Tools
TRACE, an analysis tool available from Trane Company, was used to analyze building envelope performance and to size HVAC equipment.

Energy Efficient Building Shell
An innovative exterior insulation system with a continuous air infiltration barrier was used. Special care was taken to connect and tape the barriers at all roof/wall and wall/floor joints, resulting in a continuous barrier around the entire structure. To ensure the integrity of this barrier, all cabling is routed through interior partitions, meaning that there are no penetrations (for cable, outlets, etc.) on the outside walls and therefore no holes in the infiltration barrier.

Environmentally Preferable Materials and Products
Water-based mastics and paints were used throughout the school, as was carpet with low odor emission. The carpet is also recyclable.

The Building Blocks of Boscawen Elementary

Environmentally Responsive Site Planning

Existing wetlands were preserved, as was a stream that runs through the site. Prevailing winds and sun angles were used to help determine optimal building placement on the site.

High Performance Heating, Ventilating, and Air Conditioning (HVAC)

Heat is provided by gas-fired boilers with high-efficiency controls. 100% fresh air is used for ventilation. Before the air is exhausted to the outside, heat exchangers recover 60 to 75 percent of its heat, which is then used to warm incoming fresh air.

Air conditioning is not provided. Instead, during seasons when heating is not needed, moisture is removed from the incoming air by dehumidifiers and then pumped through the ventilation system throughout the school. This strategy provides 70 to 80 percent of the benefits of full air conditioning at roughly 60 percent of the cost. Thermostats are provided in each classroom, allowing teachers to set the temperature anywhere from 68 to 74 degrees.

High Performance Electric Lighting

Direct/indirect lighting fixtures, with T-8 lamps and electronic ballasts, are used to provide even, glare-free light. The fixtures have three lamps that are separately switched, allowing the teacher to have the center tube on, the two outer tubes on, or all three tubes on, depending on specific needs and the amount of daylight being provided by the windows. Accent lighting is provided for marker boards. The equipment uses roughly 1.1 watts per square foot of power; significantly less than the 1.5 - 2.0 found in most New Hampshire schools.

Life Cycle Cost Analysis

Life cycle impacts were informally analyzed by the design team and the construction manager over the course of the project. A formal life cycle cost analysis tool was not used.

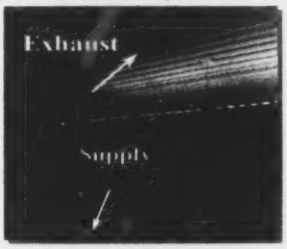
Renewable Energy

The overall orientation of the building was influenced by the prevailing winds. The gym and cafeteria were consciously located on the northwest side of the building to block the winds from the courtyard and the rest of the school. Entrance doors were also located out of the direct path of the winds.

Safety and Security

'Room-like', non-institutional corridors and plenty of views out and in were used to improve safety and provide a sense of security. A special light (that is only turned on at night) was also placed over each window. The lights are an inexpensive way to make the school appear occupied at night (i.e., without having to turn on all the lights) and have proven effective at keeping the building free from vandalism.

Displacement System



In the displacement ventilation system, fresh air is brought into the building, filtered, and passed through heat exchangers which warm it. The air is then pumped at low velocity to the classrooms where it is delivered through diffusers near the floor. The fresh, warm air slowly rises through the rooms until it is finally removed through ceiling vents. The air then passes back through the heat exchangers before it is exhausted to the outside. The heat that it 'gives up' to the

"I'm not getting the headaches and the vague, 'general malaise' complaints I used to in the old building. And it's nice to see that the asthmatics aren't having as difficult a time."

– Eileen Jones
Nurse, Boscawen Elementary

The Building Blocks of Boscawen Elementary

"Folks haven't stopped smiling since we moved in – the children, the teachers, even the parents. This is the most beautiful school I've ever worked in."

– Jane Lacasse
Principal, Boscawen Elementary

Superior Indoor Air Quality
The innovative, 'displacement air' ventilation system provides 100% fresh air to the classrooms. This air is filtered by a specialized system that removes pollen, dust, and other particulates down to one micron. Unlike most air conditioned classrooms, no air is recycled and all the air is highly filtered. As a result, indoor air quality at Boscawen is extremely high. So high, in fact, that in 1996, the school received an Environmental Merit Award from the U.S. Environmental Protection Agency. 'Walk-off mats' are also provided at entrances to reduce the amount of dirt and other pollutants entering the building.

Thermal Comfort
Individual thermostats are provided in each classroom to allow greater control over comfort conditions. The low velocity ventilation system eliminates drafts and hot or cold spots. The overall configuration of the classroom encourages vertical air stratification, ensuring that the temperature of the air surrounding the occupants remains in the comfort zone.

Visual Comfort
Windows were designed and placed so as to minimize glare. Ceilings were also designed to minimize shadows and dark areas. The colors in each room were also closely analyzed – with substantial input from teachers – in order to provide optimum visual comfort.

Students and their teacher enjoy the benefits of daylighting and other sustainable design features at Boscawen Elementary.

Water Efficiency
Low flow fixtures and low flush toilets are used throughout the school.

Facts & Figures

School Name:	Boscawen Elementary School
Location:	Boscawen, New Hampshire
Principal:	Mr. Richard Flagg
School District:	Merrimack Valley
Superintendent:	Dr. Michael Martin
Grades:	K-5
Current Students:	410
Core Capacity:	550
Size of Building:	53,000 square feet
Size of Site:	90 acres
Year Constructed:	1996
Site Cost:	$800,000
Construction Cost:	$3,445,000
Cost Per Square Foot (Building):	$65.00
Architect:	H.L. Turner Group, Concord, NH
Construction Manager:	The MacMillin Company, Keene, NH

Resources

Acoustical Society of America
2 Huntington Quadrangle, Suite 1NO1
Melville, NY 11747-4502
t: 516-576-2360
f: 516-576-2377
e: asa@aip.org
http://asa.aip.org

American Institute of Architects (AIA)
Committee on the Environment (COTE)
1735 New York Ave., NW
Washington, DC 20006
t: 202-626-7300
www.e-architect.com

American Institute of Architects/ California Council
1303 J Street, Suite 200
Sacramento, CA 95814-2935
t: 916-448-9082
f: 916-440-5346
www.aiacc.org

American Solar Energy Society (ASES)
2400 Central Avenue, Suite G-1
Boulder, CO 80301
t: 303-443-3130
f: 303-443-3212
e: ases@ases.org
www.ases.org/solarguide

The Association of California School Administrators (ACSA)
1517 L Street
Sacramento, CA 95814
t: 916-444-3216
f: 916-444-3739
www.acsa.org

Association of School Business Officials (ASBO)
11401 North Shore Drive
Reston, VA 20190
t: 703-478-0405
f: 703-478-0205
www.asbointl.org

California Association of School Board Officials (CASBO)
1531 I Street, Suite 310
Sacramento, CA 95814
Tt: 916-447-3783
Ff: 916-447-3794
www.casbo.org

California School Boards Association (CSBA)
3100 Beacon Blvd.
West Sacramento, CA 95691
t: 916-371-4691
f: 916-371-3407
www.csba.org

California Energy Commission
1516 Ninth Street
Sacramento, CA 95814-2950
t: 916-654-4989
www.energy.ca.gov

Coalition for Adequate School Housing (C.A.S.H.)
Greg Golik
c/o Murdoch, Walrath & Holmes
1130 K Street, Suite 210
Sacramento, CA 95814
t: 916-448-8577
www.cashnet.org

Collaborative for High Performance Schools (CHPS)
c/o Eley Associates
142 Minna Street
San Francisco, California 94105
t: 415-957-1977
www.chps.net

Council of Educational Facility Planners, International
9180 East Desert Cove, Suite 104
Scottsdale, AZ 85260
t: 480-391-0840
www.cefpi.org

Database of State Incentives for Renewable Energy (DSIRE)
North Carolina Solar Center
Box 7401, N.C. State University
Raleigh, North Carolina 27695-7401
t: 919-515-3480 or 800-33-NC SUN (toll-free in N.C.)
www-solar.mck.ncsu.edu/dsire.htm

Energy Smart Schools Program
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0121
t: 800-DOE-3732
www.eren.doe.gov/buildings/rebuild

Green Schools Program
Alliance to Save Energy
1200 18th Street, NW, Suite 900
Washington, DC 20036
t: 202-857-0666
www.ase.org/greenschools

Heschong Mahone Group
11626 Fair Oaks Blvd., #302
Fair Oaks, CA 95628
t: 916-962-7001
f: 916-962-0101
www.h-m-g.com

Interstate Renewable Energy Council
PO Box 1156
Latham, New York 12110-1156
t: 518-458-6059
www.irecusa.org

Leadership in Environmental and Energy Design™ (LEED)
U.S. Green Building Council
1015 18th Street, NW, Suite 805
Washington, DC 20036
t: 202-82-USGBC (828-7422)
www.leedbuilding.org

National Clearinghouse on Educational Facilities (NCEF)
NCEF at National Institute of Building Sciences
1090 Vermont Avenue, NW, Suite 700
Washington, DC 20005-4905
t: 202-289-7800 or 888-552-0624
www.edfacilities.org

National Concrete Masonry Association (NCMA)
2302 Horse Pen Road
Herndon, VA 20171-3499
t: 703-713-1900
f: 703-713-1910
www.ncma.org

National School Boards Association (NSBA)
1680 Duke Street
Alexandria, VA 22314
t: 703-838-6722
f: 703-683-7590
www.NSBA.org

Pacific Gas & Electric Company
851 Howard Street
San Francisco, CA 94103
t: 415-973-7268
http://www.pge.com/010_contact/index.shtml

Pacific Energy Center
851 Howard Street
San Francisco, CA 94103
t: 415.973.7268
f: 415.896.1290
www.pge.com/003_save_energy/003c1_pac_energy.shtml

Rebuild America Program
U.S. Department of Energy
1000 Independence Avenue, SW, EE-41
Washington, DC 20585-0121
t: 202-586-9445 or 800-DOE-3732
www.eren.doe.gov/buildings/rebuild

Schools Going Solar
Utility PhotoVoltaic Group
1800 M Street, N.W., Suite 300
Washington, DC 20036-5802
t: 202-857-0898
www.ttcorp.com/upvg/schools/index.htm

Solar Schools
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0121
www.eren.doe.gov/solarschools

Southern California Edison Company
6042 N. Irwindale Ave., Suite B
Irwindale, CA 91702
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www.sce.com

Sustainable Buildings Industry Council (SBIC)
1331 H Street, NW, Suite 1000
Washington, DC 20005-4706
t: 202-628-7400
f: 202-393-5043 (fax)
e: SBIC@SBICouncil.org
www.SBICouncil.org

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400 Maryland Avenue, SW
Washington, DC 20202-0498
t: 800-USA-LEARN
www.ed.gov

U.S. Environmental Protection Agency
Energy Star Program
Ariel Rios Building
1200 Pennsylvania Ave., NW
Washington, DC 20460
t: 202-586-9130 or 800-STAR-YES
www.energystar.gov

U.S. Environmental Protection Agency
Indoor Environment Division, Region 9
t: 415-744-1047 or 800-438-4318
www.epa.gov/iaq

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1015 18th Street, NW, Suite 805
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www.usgbc.org

Whole Building Design Guide
www.wbdg.org